

FINAL

**Intrinsic Remediation
Treatability Study for the Upper Naknek Site (SS-12)**



**King Salmon Airport
Alaska**

Prepared For

**Air Force Center for Environmental Excellence
Technology Transfer Division
Brooks Air Force Base, Texas
San Antonio, Texas**

and

**Elmendorf Air Force Base
Anchorage, Alaska**

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14 October 1999

Mr. Jerry Hansen
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Subject: Submittal of the Final Treatability Study in Support of Intrinsic Remediation for the Upper Naknek Site (SS-12), King Salmon Airport, Alaska (Contract F41624-92-D-8036-0006)

Dear Mr. Hansen:

Enclosed please find two copies of the October 1999 Final Treatability Study (TS) in Support of Intrinsic Remediation for the Upper Naknek Site (SS-12), King Salmon Airport, Alaska. This report was prepared by Parsons Engineering Science, Inc. (Parsons ES) for the Air Force Center for Environmental Excellence Technology Transfer Division (AFCEE/ERT) and Elmendorf Air Force Base (AFB).

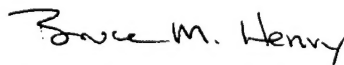
The intent of the TS was to determine the role of natural attenuation in remediating fuel contamination in groundwater at the SS-12 site. The draft TS was submitted to AFCEE in April 1995. Comments on the draft report were received from AFCEE as reviewed by Mr. Jon Atkinson of AFCEE dated 7 February 1997. Responses to these comments were prepared by Parsons ES and are attached in Appendix E.

In addition, groundwater sample data collected by the US Environmental Protection Agency (USEPA) National Risk Management Research Laboratory (NRMRL) in September 1998 has been evaluated and incorporated into this Final TS as an addendum (Appendix F) under Air Mobility Command (AMC) Contract F11623-94-D0024-RL71. Conclusions from the addendum were further included in the Final TS Executive Summary.

If you have any questions or comments regarding this package, please do not hesitate to contact me at (303) 831-8100.

Sincerely,

PARSONS ENGINEERING SCIENCE, INC.



Bruce M. Henry, P.G.
Project Manager

Enclosures

c.c. Mr. Don Kampbell – USEPA NRMRL
Mr. Jonathon Decker – Parsons ES (w/o enclosure)

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**FINAL
INTRINSIC REMEDIATION TREATABILITY STUDY**

for the

**UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT, ALASKA**

October 1999

Prepared for:

**AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
TECHNOLOGY TRANSFER DIVISION
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS**

and

**ELMENDORF AFB
ANCHORAGE, ALASKA**

Prepared by:

**Parsons Engineering Science, Inc.
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EXECUTIVE SUMMARY

This report presents the results of a treatability study (TS) performed by Parsons Engineering Science, Inc. (Parsons ES) at King Salmon Airport, Alaska. The purpose of the TS was to evaluate the use of intrinsic remediation (natural attenuation) with long-term monitoring (LTM) as a remedial option for dissolved benzene, toluene, ethylbenzene, and xylene (BTEX) contamination in the vicinity of the Upper Naknek Site (SS-12). The Naknek Site consists of numerous spill sources and is divided into the Upper and Lower Naknek Sites. Only the fuel releases and related hydrocarbon contamination emanating from the Upper Naknek Site were studied in this investigation. Soil and groundwater contamination at the Upper Naknek Site is present in the aqueous and gaseous phases and as residual light nonaqueous-phase liquid (LNAPL) within the aquifer matrix. Limited evidence suggests that some mobile LNAPL may also be present at the site. The precise source of residual LNAPL contamination remains undefined.

A two-dimensional finite-difference model, Bioplume II, was used to estimate the rate and direction of dissolved BTEX migration through the shallow saturated zone (A-Aquifer) under the influence of advection, dispersion, sorption, and biodegradation. Input parameters for the Bioplume II model were obtained from existing site characterization data, supplemented with data collected by Parson ES in conjunction with personnel from the United States Environmental Protection Agency (USEPA) National Risk Management Research Laboratory (NRMRL, formerly the Robert S. Kerr Environmental Research Laboratory). Extensive site-specific data were used for model implementation. Model parameters that were not measured at the site were estimated using reasonable literature values. The results of this study suggest that dissolved BTEX contamination present in shallow groundwater poses no significant threat to human health or the environment in its present, or predicted future, concentrations and distribution because it is unlikely that exposure pathways will be completed.

Limited assessments of hydrocarbon impacts in surface waters and sediments of an adjacent wetland, and in the lower confined aquifer (B-Aquifer) were also conducted during this study. Data collected during site characterization suggest that these media have been impacted to an undetermined extent. In both cases, it is believed that the site conditions are sufficient to promote natural attenuation of contaminants in these media to concentrations below regulatory action levels before impact to potential receptors.

Additional groundwater sampling was performed by the USEPA NRMRL in July 1995 and September 1998. Without remediation of the source (i.e., mobile and residual phase LNAPL), natural attenuation is the only process acting to control the BTEX groundwater plume at Site SS-12 from September 1994 to date. The wells sampled in September 1998 do not provide adequate data to delineate the downgradient extent of the BTEX plume. However, from September 1994 to September 1998 BTEX concentrations increased in 5 of the 7 wells sampled in 1998. BTEX concentrations in the most contaminated well (ESMW-8A) did decrease from 8,740 micrograms per liter ($\mu\text{g/L}$) in July 1995 to 7,120 $\mu\text{g/L}$ in September 1998.

Geochemical indicators measured in 1995 and 1998 continue to support the occurrence of intrinsic bioremediation at the site. Aerobic degradation is expected to continue mainly in the in the upgradient perimeter of the source area and along the fringes of the plume. Anaerobic biodegradation processes of iron reduction and methanogenesis appear to be the predominant destructive attenuation mechanisms in the core of the plume. In July 1995 and September 1998, dissolved oxygen (DO) and oxidation-reduction potential (ORP) measurements suggest the presence of a reducing groundwater environment in the core of the BTEX plume. The correlation between low DO and ORP measurement with accumulation of methane and ferrous iron further support that methanogenesis and iron reduction are biotically degrading BTEX compounds at the site. An increase in BTEX concentrations in the downgradient toe and deeper portions of the plume appear to be offset by increasing microbial activity at those locations as evidenced by increasing ferrous iron concentrations, decreasing sulfate concentrations, and increasing methane concentrations.

In addition to proposed LTM for the shallow groundwater, Parsons ES recommends that LTM also be implemented for the B-Aquifer and the adjacent wetland to support the intrinsic remediation approach for these media. To verify predictions that intrinsic remediation will reduce hydrocarbon contamination in groundwater, Parsons ES recommends using five LTM locations and three nested point-of-compliance (POC) monitoring wells to monitor the long-term migration and degradation of dissolved BTEX in both the A-Aquifer and the B-Aquifer. The nested POC locations will contain one screened interval in each aquifer. To verify that hydrocarbon contamination is nonexistent or that intrinsic remediation is mitigating hydrocarbon contamination in the adjacent wetland to below regulatory action levels, Parsons ES recommends surface water and sediment sampling at four wetland locations. In addition, Parsons ES recommends that a source identification study be performed to define the extent of residual soil contamination. Eliminating potential sources would expedite natural attenuation of existing contamination in soil and groundwater at the site.

If BTEX concentrations in groundwater samples from the recommended POC wells exceed the federal regulatory standards of 5 µg/L for benzene, 1,000 µg/L for toluene, 700 µg/L for ethylbenzene, or 10,000 µg/L for total xylenes, additional corrective actions may be required to remediate groundwater at the site. If hydrocarbon contaminant concentrations in surface water or sediment in the wetland exceed state quality criteria, additional corrective actions (e.g., a predictive risk assessment) may be required to remediate surface waters and soils at the site.

Regular sampling and analysis of groundwater, surface water, and sediment at the Upper Naknek Site will support the effectiveness of intrinsic remediation, and should allow sufficient time to implement engineered controls to contain contaminant migration if contamination in any of the affected media exceeds action levels at the respective POCs. On the basis of site data and modeling results, LTM should continue on an annual basis for at least 15 years.

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LIST OF ACRONYMS AND ABBREVIATIONS

2-D	2-dimensional
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
AST	aboveground storage tank
atm-m ³ /mol	atmosphere-cubic meters per mole
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
CEOS	Civil Engineering Operations Squadron
°C	degrees Celsius
DO	dissolved oxygen
DRO	diesel-range organic
ES	Engineering-Science, Inc.
Fe ²⁺	ferrous iron
Fe ³⁺	ferric iron hydroxide
ft/ft	foot per foot
ft/min	feet per minute
ft/sec	feet per second
ft/yr	feet per year
ft ³ /sec	cubic feet per second
g/cc	grams per cubic centimeter
GAC	granular activated carbon
GC/MS	gas chromatography/mass spectrometer
HSA	hollow-stem auger
ID	inside diameter
IRP	Installation Restoration Program
JP-4	jet fuel
K _{oc}	soil sorption coefficient
KSA	King Salmon Airport
LFS	limited field study
LNAPL	light, nonaqueous-phase liquid
LTM	long-term monitoring
MCL	maximum contaminant level
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mm Hg	millimeters of mercury
MOC	method of characteristic
msl	mean seal level
mV	millivolts
NORAD	North American Air Defense Command
NRMRL	National Risk Management Research Laboratory
ORP	reduction/oxidation potential
Parsons ES	Parsons Engineering Science, Inc.
PCE	tetrachloroethene

PID	photoionization detector
POC	point of compliance
POL	petroleum, oils, and lubricants
PVC	polyvinyl chloride
QC	quality control
R	retardation
RAOs	remedial action objectives
redox	reduction/oxidation
RI/FS	remedial investigation/feasibility study
RMS	root mean square
RSKERL	Robert S. Kerr Environmental Research Laboratory
SAIC	Science Application International Corporation
TCE	trichloroethene
TMB	trimethybenzene
TOC	total organic carbon
TRPH	total recoverable petroleum hydrocarbon
TS	Treatability Study
USACE	US Army Corps of Engineers
USEPA	US Environmental Protection Agency
USGS	US Geological Survey
UST	underground storage tank
VOCs	volatile organic compounds

SECTION 1

INTRODUCTION

This report was prepared by Parsons Engineering Science, Inc. (Parsons ES) [formerly Engineering-Science, Inc. (ES)] and presents the results of a Treatability Study (TS) conducted to evaluate the use of intrinsic remediation (natural attenuation) for remediation of fuel-hydrocarbon-contaminated groundwater at the Upper Naknek Site (Site SS-12), King Salmon Airport (KSA), King Salmon, Alaska. The site was used as a petroleum, oil, and lubricants (POL) tank farm (primarily JP-4 jet fuel) comprised of numerous underground storage tanks (USTs) and aboveground storage tanks (ASTs). Previous investigations determined that fuel hydrocarbons had been released into the soil and shallow groundwater at the site from petroleum hydrocarbons contained in the USTs, ASTs, and/or POL lines.

The main emphasis of the work described herein was to evaluate the potential for naturally occurring degradation mechanisms to reduce dissolved benzene, toluene, ethylbenzene, and xylene (BTEX) concentrations in groundwater to levels that meet federal- and state-specified groundwater protection standards.

1.1 SCOPE AND OBJECTIVES

Parsons ES, in conjunction with researchers from the United States Environmental Protection Agency (USEPA) Robert S. Kerr Environmental Research Laboratory (RSKERL), was retained by the United States Air Force Center for Environmental Excellence (AFCEE) to conduct site characterization and groundwater modeling activities in support of intrinsic remediation with long-term monitoring (LTM).

There were two primary objectives of this report:

- Determine whether naturally occurring attenuation processes for fuel hydrocarbons are occurring in groundwater at the site, and, if so,
- Investigate if these processes are sufficient to minimize the expansion of the fuel hydrocarbon plume using the Bioplume II model to ensure that federal- and state-specified groundwater protection standards will be met at a downgradient point of compliance (POC).

These objectives were accomplished by:

- Reviewing existing hydrogeologic and soil and groundwater quality data for the site;

- Conducting supplemental site characterization activities to determine the nature and extent of soil and groundwater contamination and to collect geochemical data in support of intrinsic remediation;
- Developing a conceptual hydrogeologic model of the shallow saturated zone, including the current distribution of contaminants;
- Determining if naturally occurring processes of contaminant attenuation are occurring in groundwater at the site;
- Performing contaminant fate and transport modeling based on site hydrogeologic conditions using the Bioplume II model;
- Evaluating a range of model input parameters to determine the sensitivity of the model to those parameters and to consider several contaminant fate and transport scenarios;
- Determining if naturally occurring processes are sufficient to minimize BTEX plume expansion so that groundwater quality standards can be met at a downgradient POC;
- Developing remedial action objectives (RAOs) and reviewing available remedial technologies;
- Using the results of modeling to recommend the most appropriate remedial option based on specific effectiveness, implementability, and cost criteria; and
- Providing a LTM plan that includes LTM and POC well locations and a sampling and analysis plan.

Site characterization activities in support of intrinsic remediation included soil borehole drilling with soil sample collection and analysis, monitoring well installation, and sampling and analysis of groundwater from newly installed and existing monitoring wells. Additional groundwater sampling was performed in July 1995 and September 1998 by the USEPA National Risk Management Research Laboratory (NRMRL, formerly the RSKERL). Data from these sampling events were not available for analysis in preparation of this TS, but have been analyzed in an addendum to this TS (Appendix F).

Site-specific data were used to develop a fate and transport model for the site using Bioplume II and to conduct a preliminary exposure pathway analysis. The Bioplume II model was used to simulate the movement of dissolved BTEX in the shallow saturated zone under the influence of advection, dispersion, sorption, and biodegradation. As part of the TS, model results were used to determine if intrinsic remediation with LTM is an appropriate and defensible remedial option for contaminated groundwater.

Several remedial options were considered to identify the major advantages and disadvantages associated with different groundwater remedial strategies. Other remedial technology options briefly considered in this document include groundwater extraction and treatment (i.e., pump and treat), air sparging, and slurry walls/grout curtains for an *in situ* barrier system. Most of the hydrogeological and groundwater chemical data necessary to

evaluate the various remedial options were collected in September 1994 by Parsons ES. Supplemental data derived from previous investigation reports and technical literature were also considered in this investigation. The field work conducted under this program was oriented toward the collection of hydrogeologic data to be used as input into the Bioplume II groundwater model in support of intrinsic remediation with LTM for restoration of fuel-hydrocarbon-contaminated groundwater.

This report contains nine sections, including this introduction, and six appendices. Section 2 summarizes site characterization activities. Section 3 summarizes the physical characteristics of the study area. Section 4 describes the nature and extent of soil and groundwater contamination and the geochemistry of soil and groundwater at the site. Section 5 describes the Bioplume II model and design of the conceptual model for the site, lists model assumptions and input parameters, and describes sensitivity analysis, model output, and the results of Bioplume II modeling. Section 6 presents a comparative analysis of remedial alternatives. Section 7 presents the LTM plan for the site. Section 8 presents the conclusions of this work and provides recommendations for further work at the site. Section 9 lists the references used to develop this document. Appendix A contains boring logs and well completion diagrams. Appendix B presents soil and groundwater analytical results. Appendix C contains calculations and model input parameters. Appendix D contains Bioplume II model input and output in ASCII format on a diskette. Appendix E contains an addendum to this TS based on subsequent groundwater sampling performed in July 1995 and September 1998.

1.2 FACILITY BACKGROUND

KSA is situated on a 216-acre site located on the upper, northwestern side of the Alaskan Peninsula (Figure 1.1). Anchorage, Alaska is 280 miles to the northeast. KSA is located on the northern bank of the Naknek River, facing Bristol Bay. The closest communities are the small towns of King Salmon, located adjacent to the northern boundary of KSA, and Naknek and South Naknek, located approximately 13 miles west-northwest of KSA along the Naknek River (Figure 1.2). KSA is accessible only by air or water.

KSA was previously a forward operating base, which hosted the North American Aerospace Defense Command with a contingent of F-15 Eagles on alert missions rotated from Elmendorf Air Force Base (AFB). Maintenance and support for the F-15s was provided by the 643rd Squadron as directed by the 3rd Control Wing out of Elmendorf AFB. In addition to F-15s, KSA was a base for long-range radar connected to the North American Defense (NORAD) Regional Operations Control Center at Elmendorf AFB. As of September 1, 1994, the base was deactivated and all military operations were terminated by September 14, 1994. Installation maintenance is currently performed by private contractors, and will continue for 5 years in the event that the base needs to be reactivated.

1.3 SITE BACKGROUND

The Upper and Lower Naknek Sites (collectively referred to as Site SS-12) are located on the northern bank of the Naknek River approximately 0.7 mile west of the town of King Salmon, Alaska (Figure 1.3). Site SS-12 was a POL tank farm where fuel was stored in

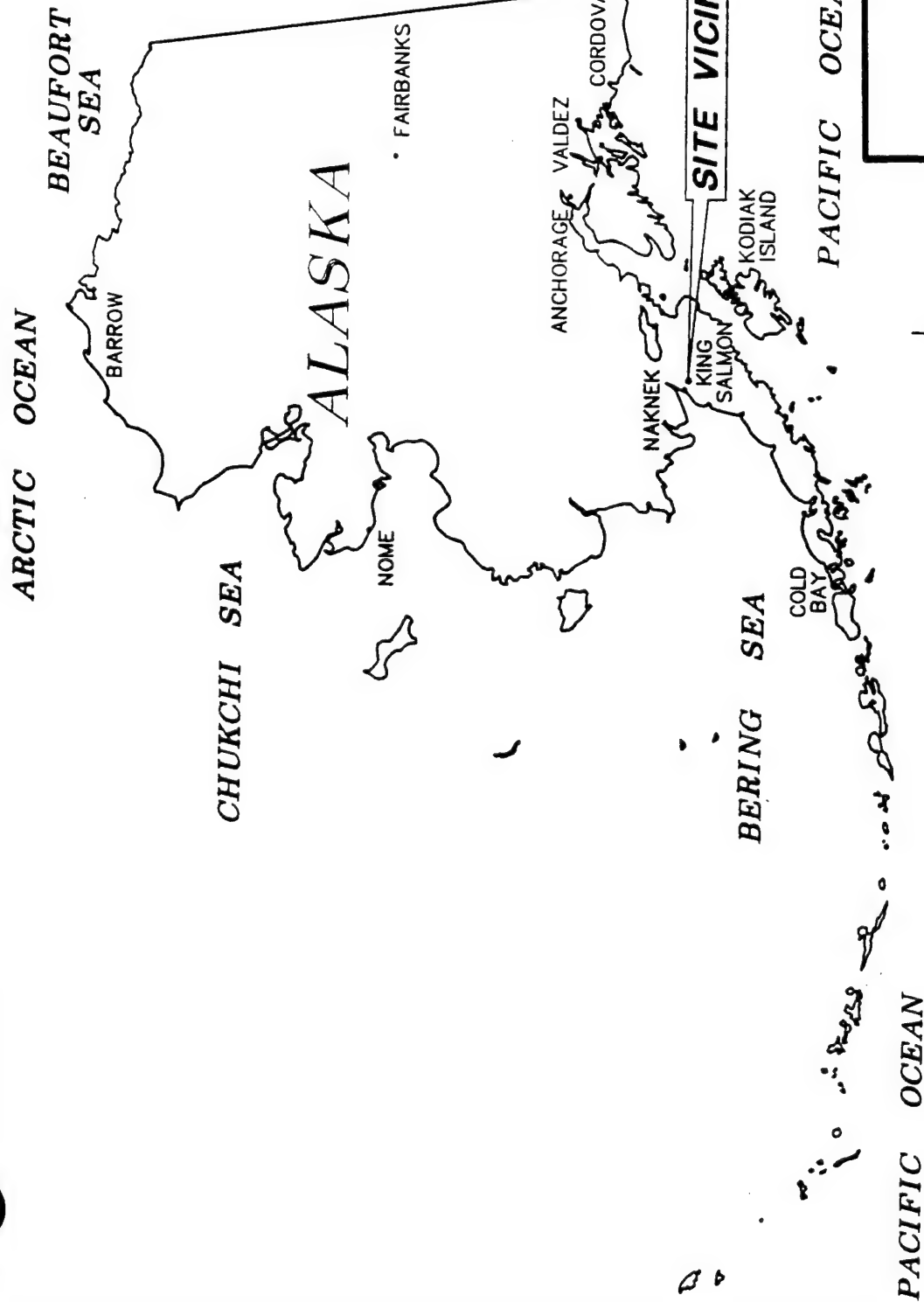


FIGURE 1.1

LOCATION OF KING SALMON AIRPORT

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska



**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

SOURCE: SAIC, 1993

1.1.1 12/01/93 00:00:00 00:00:00 00:00:00

1.1.1 12/01/93 00:00:00 00:00:00 00:00:00

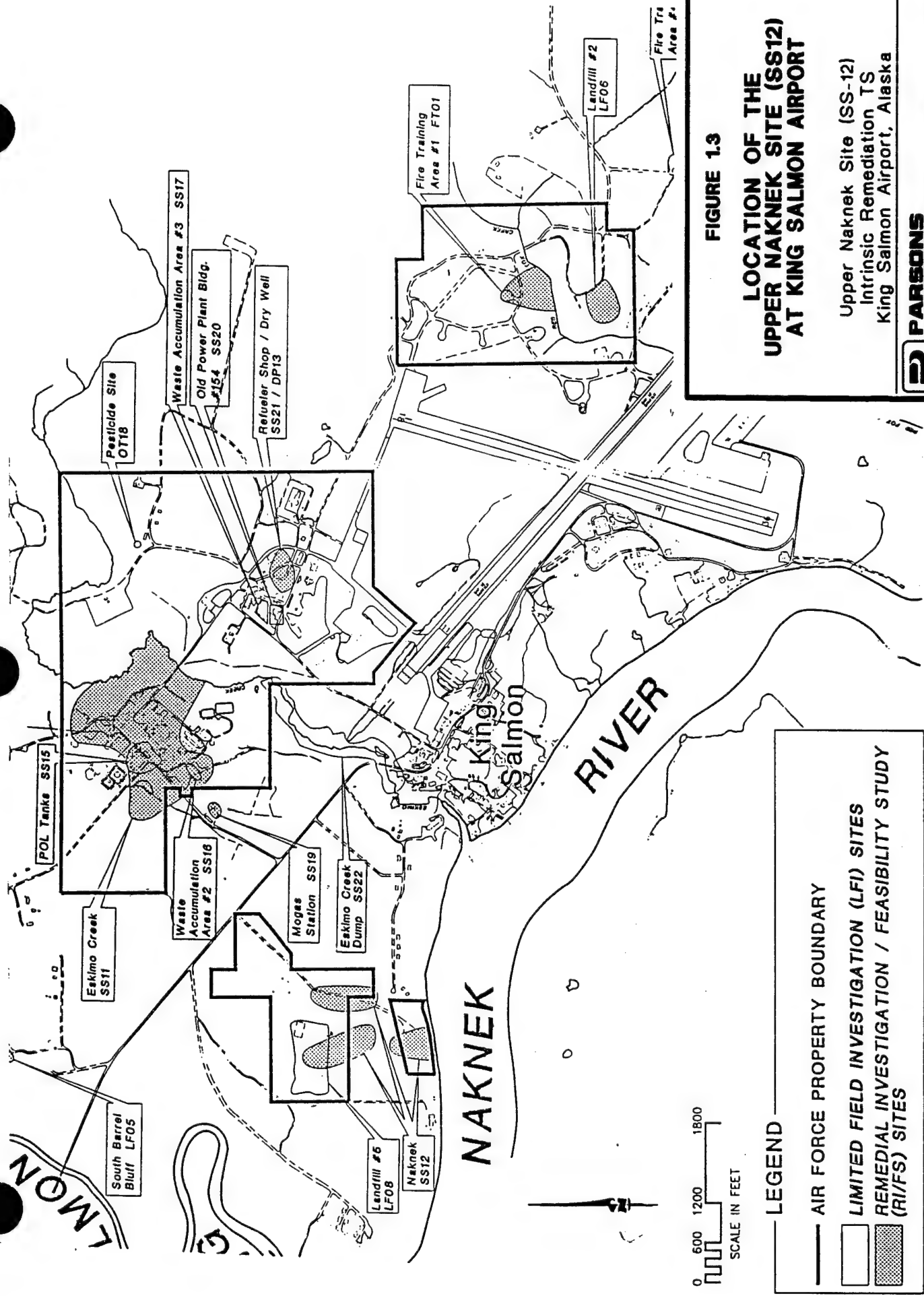


FIGURE 1.3

**LOCATION OF THE
UPPER NAKNEK SITE (SS12)
AT KING SALMON AIRPORT**

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska



**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

ASTs and USTs. A site layout of the Upper Naknek Site is shown in Figure 1.4. Fuel was supplied by barge, where it was unloaded via pipeline into the tanks and stored until needed.

Available information is limited as to locations of excavated USTs or currently operating USTs at the site. However, a previous report (EMCON, 1994a) indicates that ASTs at the Upper Naknek Site have been removed and the cumulative count of USTs having existed at the site includes: 2 25,000-gallon "Operation USTs," 24 50,000-gallon USTs, and 24 25,000-gallon USTs. Three 25,000-barrel ASTs and one 11,900-barrel AST were also located at the Lower Naknek Site. A feature of interest at the Upper Naknek Site is Landfill #5, which is located in the western portion of the site. This landfill is located adjacent to and overlaps the petroleum contamination from the Upper Naknek Site and has been targeted for a limited field study (LFS) (EMCON, 1994a). The operational dates of the landfill are unknown, but it was reportedly used as a disposal area for empty drums.

Site SS-12 has undergone previous investigations related to the facility-wide installation restoration program (IRP). Early evidence of contamination was observed as visible sheens of hydrocarbons on surface waters (Engineering-Science, Inc., 1985). Site investigations performed by CH₂M Hill from 1987 to 1990 (CH₂M Hill, 1989 and 1990) included a soil gas survey; a geophysical survey; installation of seven monitoring wells, five shallow borings, and four back-hoe test pits; and completion of slug tests at seven monitoring wells. These activities confirmed the presence of a landfill at the western end of the site and concentrations of benzene in groundwater that exceeded the federal MCL for benzene of 5 µg/L. In 1993, petroleum product seeping from the Upper Naknek Site was reported to be flowing into the Lower Naknek Site. Science Applications International Corporation (SAIC) constructed a french drain at the site to stop migration of this contamination into the Naknek River. Further studies also have documented contamination at the site. The results of previous site investigations at SS-12 are presented in the following reports:

- Installation Restoration Plan, King Salmon Airport, Stage 1, Final Technical Report (CH₂M Hill, 1989);
- Installation Restoration Plan, Stage 2, Final Draft Technical Report (CH₂M Hill, 1990);
- Report of Groundwater Monitoring Well Sampling and Analysis, King Salmon Airport, Alaska (SAIC, 1992);
- Groundwater Monitoring Performed October, 1992, King Salmon Airport, King Salmon, Alaska (SAIC, 1993a);
- Remedial Investigation/Feasibility Study at Eleven Sites, King Salmon Airport, King Salmon, Alaska (SAIC, 1993b);
- Remedial Investigation/Feasibility Study (RI/FS) at Twelve Sites, Stage 3, Part 1: Remedial Investigation, King Salmon Airport, King Salmon, Alaska (EMCON, 1994a);
- A September/October, 1994 monitoring well sampling report, King Salmon Airport, King Salmon, Alaska, September/October 1994 (EMCON, 1994b-in preparation); and

EMCON=INSTALLATION SAMPLING LOCATIONS (FALL 1993)

- 504 ○ SEDIMENT/SURFACE WATER SAMPLE PAIR
- 111 ● SOIL BORING
- 113 ○ WELL POINT (LP) WITH LABEL
- 502 ○ A-AQUIFER MONITORING WELL
- 506 ● B-AQUIFER MONITORING WELL
- BGM001 ▲ BACKGROUND METALS SAMPLE
- ↑ GROUNDWATER FLOW DIRECTION
- - - FENCE

SAMPLING LOCATIONS INSTALLED PRIOR TO FALL 1993

- MW-54 ○ MONITORING WELL
- WP3 ● WELL POINT

SAMPLING LOCATIONS INSTALLED SEPTEMBER 1994

- ESMW-14 ○ MONITORING WELL

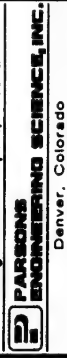
- AREA EXCAVATED IN 1992
- ▨ FORMER PRODUCT SEEP
- - - WETLANDS AREA (DASHED WHERE ESTIMATED)



FIGURE 1.4

UPPER NAKNEK SITE (SS-12)

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska



- Remedial Investigation/Feasibility Study (RI/FS) at Twelve Sites, Stage 3, Part 2: Remedial Investigation, King Salmon Airport, King Salmon, Alaska (EMCON, 1994c-in preparation).

Site-specific data presented in Sections 3, 4, and 5 are based on a review of these documents and on data collected by Parsons ES and researchers from the RSKERL under this program.

SECTION 2

SITE CHARACTERIZATION ACTIVITIES

This section presents the methods used by Parsons ES and RSKERL personnel to collect site-specific data at the Upper Naknek Site at KSA, Alaska. To meet the requirements of the intrinsic remediation demonstration, several investigative techniques, including soil and groundwater sampling, were utilized. Soil sampling was accomplished during this investigation using hollow-stem auger (HSA) drilling in conjunction with continuous split-barrel sampling. Previous investigations conducted at the site utilized standard HSA drilling and soil sampling as well as sampling of groundwater via monitoring wells. Groundwater sampling was accomplished during this investigation using newly installed and previously existing monitoring wells. Aquifer slug tests were conducted at existing wells.

The physical and chemical hydrogeologic data listed below were collected during the field work phase of the TS:

- Depth from measurement datum to the water table or potentiometric surface in monitoring wells and monitoring points;
- Location of potential groundwater recharge and discharge areas;
- Stratigraphic analysis of subsurface media;
- Estimating the extent and thickness of any mobile light nonaqueous-phase liquid (LNAPL);
- Hydraulic conductivity as determined from slug test data;
- Dissolved oxygen (DO), nitrate, ferrous iron, sulfate, methane, and chloride concentrations in groundwater;
- Temperature, specific conductance, reduction/oxidation (redox) potential, total alkalinity, and pH of groundwater;
- BTEX and trimethylbenzene (TMB) concentrations in groundwater;
- BTEX, TMB, and total fuel carbon concentrations in soil; and
- Total organic carbon (TOC) concentrations in soil and groundwater samples.

The following sections describe the procedures that were followed when collecting site-specific data. The applied drilling, soil sampling, lithologic logging, and monitoring

well development procedures are described in Section 2.1. Groundwater sampling procedures are described in Section 2.2. Additional details regarding investigative activities are presented in the draft work plan (Engineering-Science, Inc., 1994).

2.1 DRILLING, SOIL SAMPLING, AND MONITORING WELL INSTALLATION

Field work took place during September 1994, and consisted of drilling, soil sampling, and monitoring well installation for wells ESMW-8A through ESMW-15B. These activities were performed according to the procedures described in the work plan (Engineering-Science, Inc., 1994) and in the following sections.

2.1.1 Well Locations and Completion Intervals

Eleven new groundwater monitoring wells in eight locations were installed to help characterize the shallow groundwater flow system and contaminant concentrations at the Upper Naknek Site. Monitoring wells ESMW-8A through ESMW-15B were placed to collect data necessary for delineation and study of the west hydrocarbon plume at the site, as was originally stated in the site work plan (Engineering-Science, Inc., 1994). Analysis of groundwater data (Section 4) later revealed the presence of another hydrocarbon plume originating to the west of the previously defined source area. The two plumes apparently merge to form a single plume at downgradient locations. The new monitoring wells were installed in locations shown on Figure 2.1. Table 2.1 presents well completion details.

Nested wells were installed at three locations (ESMW-8, ESMW-10, and ESMW-15) to provide vertical definition of the contaminant distribution at the site. Nested well pairs were installed adjacent to each other, with one well (designated by the suffix "A") screened across the water table, and with the other well (designated by the suffix "B") screened 7 to 10 feet below the bottom of the first well. All wells were given these suffixes whether or not they were nested. The well locations were selected to provide the hydrogeologic data necessary for successful implementation of the Bioplume II model and to support intrinsic remediation.

2.1.2 Well Drilling and Soil Sampling Procedures

This section describes the procedures that were used for drilling and installation of new monitoring wells. All new monitoring wells were installed in accordance with general procedures outlined in Section 8.5 of *A Compendium of Superfund Field Methods* (EPA, 1987).

2.1.2.1 Pre-Drilling Activities

All necessary digging, drilling, and groundwater monitoring well installation permits were obtained prior to mobilizing to the field. In addition, all utility lines were located, and proposed drilling locations were cleared prior to any drilling activities.

Water used in drilling, equipment cleaning, or grouting was obtained from an onsite potable water supply. Water use approval was verified by contacting the appropriate facility personnel.

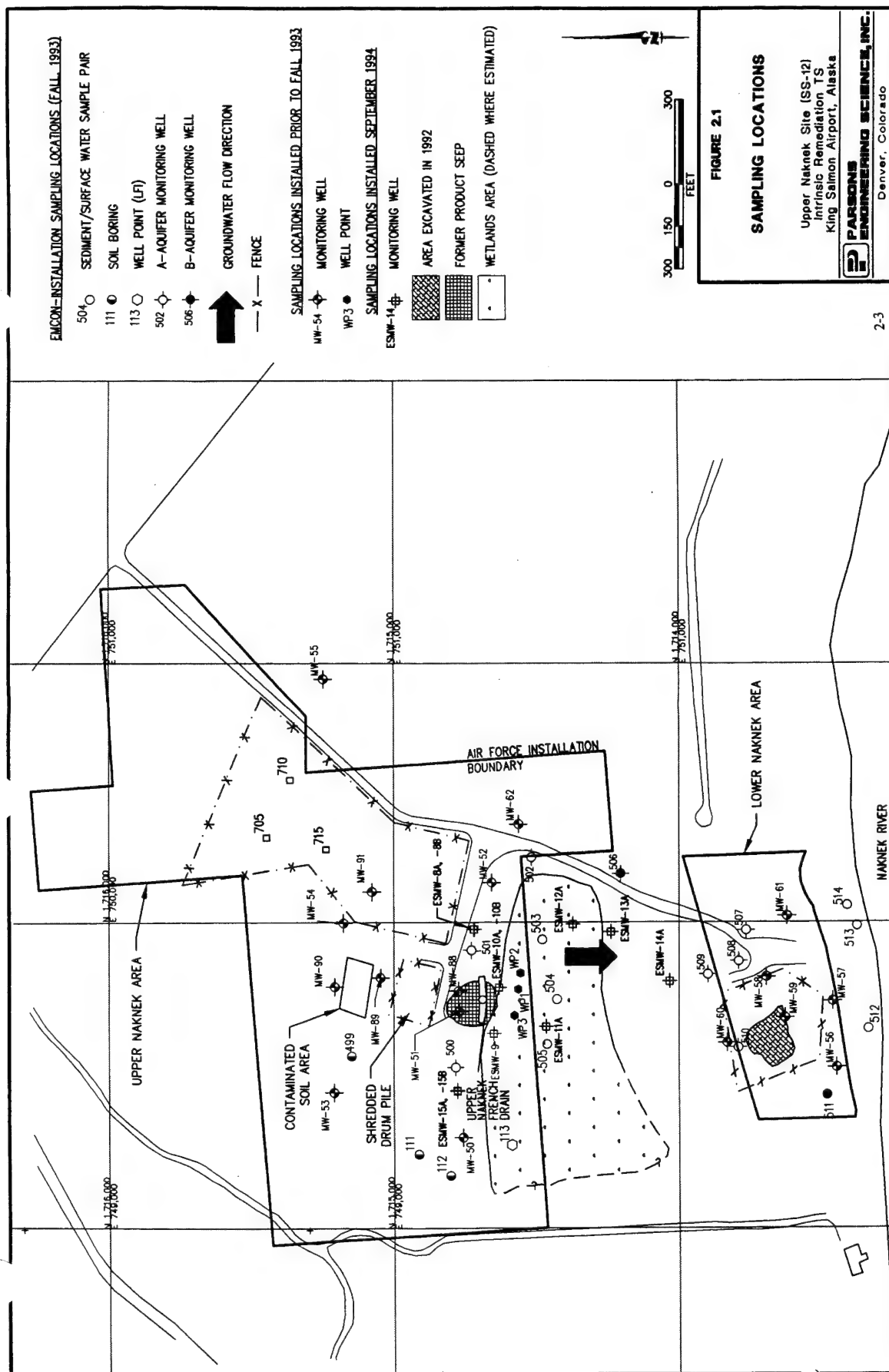


TABLE 2.1

WELL COMPLETION INFORMATION
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

Well Location	Installation Date	Northing	Easting	Well ID (inches)	Datum Elevation (ft msl) ^{a/}	Ground Elevation (ft msl)	Screen Interval	
							Top (ft bgs) ^{b/}	Bottom (ft bgs)
ESMW-8A	9/20/94	1714720.83	750058.14	2	32.29	29.15	5.3	10.3
ESMW-8B	9/20/94	1714717.78	750058.45	2	32.18	29.15	12.9	17.9
ESMW-9A	9/19/94	1714648.98	749690.77	2	25.50	21.61	0.0	4.5
ESMW-10A	9/21/94	1714630.73	749853.07	2	23.30	21.60	1.0	6.0
ESMW-10B	9/21/94	1714630.55	749852.60	2	24.18	21.60	11.0	14.0
ESMW-11A	9/19/94	1714466.90	749715.65	2	23.53	20.52	0.0	3.0
ESMW-12A	9/19/94	1714372.28	750075.50	2	23.46	NA ^{c/}	0.0	4.5
ESMW-13A	9/22/94	1714239.65	750048.82	2	24.02	21.29	5.0	10.0
ESMW-14A	9/22/94	1714034.10	749874.14	2	25.04	22.17	5.0	10.0
ESMW-15A	9/21/94	1714763.18	749487.24	2	39.10	36.30	9.0	14.0
ESMW-15B	9/21/94	1714763.46	749497.86	2	39.85	36.30	16.0	21.0
500	10/25/93	1714756.56	749686.11	2	39.91	36.90	10.0	20.0
501	10/25/93	1714750.77	749937.57	2	NA	33.30	5.0	15.0
502	10/25/93	NA	NA	2	NA	20.30	1.0	11.0
506 ^{d/}	11/9/93	1714205.22	750254.74	2	20.49	18.51	23.0	33.0
507	10/24/93	1713765.31	750054.77	2	19.22	16.89	2.0	12.0
508	10/24/93	1713791.01	749945.45	2	22.27	18.95	2.0	12.0
509	10/24/93	1713899.66	749898.95	2	24.29	21.52	3.0	13.0
510	10/24/93	NA	NA	2	NA	23.30	3.0	13.0
MW-50	8/14/89	1714786.19	749323.67	2	35.63	34.05	4.3	14.3
MW-51	8/14/89	1714770.25	749488.43	2	33.74	32.57	6.7	16.7
MW-52	8/13/89	1714656.18	750223.58	2	25.74	24.39	0.25	9.8
MW-53	7/30/89	1715210.10	749482.68	2	45.15	43.81	9.9	19.9
MW-54	8/12/89	1715177.35	750080.86	2	43.78	42.16	8.3	18.3
MW-55	8/2/89	1715248.19	750946.95	2	44.55	43.06	10.9	20.9
MW-56	8/17/89	NA	NA	2	NA	17.00	1.5	6.5
MW-57	8/6/89	1713498.45	749844.43	2	NA	17.86	0.0	10.0
MW-58	8/16/89	1713694.49	749889.21	2	20.01	18.88	0.4	10.4
MW-59	8/16/89	NA	NA	2	NA	19.00	1.2	11.2
MW-60	8/15/89	1713829.21	749657.07	2	25.41	24.42	1.6	11.6
MW-61	8/8/89	1713624.14	750104.32	2	19.33	19.33	2.4	7.4
MW-62	8/8/89	NA	NA	2	NA	20.00	0.5	4.5
MW-88	9/3/92	1714766.78	749842.40	2	35.98	34.01	8.0	28.0
MW-89	9/4/92	1715046.90	749888.56	4	38.16	37.26	8.0	28.0
MW-90	9/7/92	1715209.67	749856.27	4	46.44	44.46	9.0	29.0
MW-91	9/28/92	1715077.52	750191.76	4	40.68	38.08	4.0	24.0
WP-1	NA	1714563.42	749846.84	2	23.76	19.80	NA	NA
WP-2	NA	1714555.47	749902.60	2	24.33	20.38	NA	NA
WP-3	NA	1714576.10	749753.82	2	24.70	20.77	NA	NA

^{a/} ft msl=Feet above mean sea level.

^{b/} ft bgs=Feet below ground surface.

^{c/} NA=Not Available.

^{d/} 506 was screened in the B-aquifer.

2.1.2.2 Equipment Decontamination Procedures

Prior to arriving at the site, and between each drilling location, the augers, drilling rods, bits, casing, samplers, tools and other downhole equipment were decontaminated using a high-pressure, steam/hot water wash. Only potable water was used for decontamination.

During drilling operations, the drill rig, augers, and any downhole drilling and/or sampling equipment were decontaminated at a site decontamination pad. Water from the steam/hot water wash operation was allowed to collect in the decontamination pad and then conditioned by pumping through a granular activated carbon (GAC) unit. After treatment in the GAC unit, water was stored in a 500-gallon holding tank. Water from the holding tanks was eventually released into an on-site sanitary sewer. Precautions were taken to minimize any impact to the area surrounding the decontamination pad that might result from the decontamination operations.

All sampling tools were cleaned onsite, prior to use and between each sampling event, with a clean water/phosphate-free detergent mix and a clean water rinse. All well completion materials were factory sealed. All decontamination activities were conducted in a manner so that the excess water was controlled and not allowed to flow into any open borehole.

Fuel, lubricants, and other similar substances were handled in a manner consistent with accepted safety procedures and standard operating practices. Well completion materials were not stored near or in areas that could be affected by these substances.

2.1.2.3 Drilling and Soil Sampling

Drilling was accomplished by using the HSA method. The borings were drilled and continuously sampled to the total depth of the borehole. Where two wells were installed adjacent to each other (i.e., nested), only the deeper well was logged and sampled. In many instances, sand heave below the water table prevented collection of continuous samples. A final borehole diameter of at least 8 inches was used for the installation of wells with a 2-inch inside-diameter (ID) casing.

Continuous soil samples were obtained using a 2.5-inch-ID split-barrel sampling device (also known as a split spoon). Where possible, samples were collected continuously over the full depth of the soil borehole. Soil samples were removed from the split spoon as composites of soil from 1-foot intervals, and then placed in clean glass jars for laboratory analysis. In addition, a portion of the soil sample was placed in an unused, sealable plastic bag for photoionization detector (PID) headspace measurements for volatile organic compounds (VOCs). Soil remaining in the spoon was used for lithologic and stratigraphic logging. Bags containing soil samples collected for the headspace procedure were quickly sealed and held for 15 minutes at ambient air temperatures within the confines of a site vehicle. Semiquantitative measurements were made by puncturing the bag seal with the PID probe and reading the concentration of the headspace gases. The PID relates the concentration of total VOCs in the sample to an isobutylene calibration standard. The PID was also used to monitor the worker breathing zone.

The Parsons ES field hydrogeologist observed drilling and well installation activities and maintained a detailed descriptive log of subsurface materials recovered. Final geologic boring logs are presented in Appendix A. These logs contain:

- Sampled interval (top and bottom depth);
- Presence or absence of contamination based on odor, staining, and/or PID readings;
- Soil description, including color, major textural constituents, minor constituents, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, and any other significant observations; and,
- Lithologic contacts, with the depth of lithologic contacts and/or significant textural changes recorded to the nearest 0.1 foot (1 inch).

At all borehole locations, one or two soil samples from the vicinity of the water table were selected for laboratory analysis. Where no elevated PID headspace readings were encountered, samples were collected from immediately above and/or immediately below the water table. Where PID readings were elevated, one of the samples submitted for laboratory analysis was from the interval that had the highest reading.

Sample containers and appropriate container lids were provided by the EPA Mobile Laboratory. The sample containers were filled as full as possible to eliminate creation of headspace in the jars, and the container lids were tightly closed. A sample label was firmly attached to the container side, and the following information was legibly and indelibly written on the label:

- Sample identification;
- Sample depth;
- Sampling date; and,
- Sample collector's initials.

After the samples were sealed and labeled, they were placed in a cooler with ice and held for transport to the onsite EPA Mobile Laboratory. Samples were analyzed for BTEX, total fuel carbon (as JP-4), trimethylbenzenes (TMBs), TOC, tetrachloroethene (PCE), and trichloroethene (TCE). Soil analytical protocol is listed on Table 2.2.

All soils were initially drummed and stored near the monitoring wells during the drilling operations. Soils at the site were eventually relocated to a soil farm specifically designed for petroleum-hydrocarbon-contaminated soils and maintained by the 11th Civil Engineering Operations Squadron (CEOS).

2.1.3 Monitoring Well Installation

Groundwater monitoring wells were installed in seven soil borings under this program. Monitoring wells at three locations (ESMW-9, ESMW-11, and ESMW-12) were installed in hand-augered bore holes in order to avoid damage to surrounding wetland areas by

TABLE 2.2
SUMMARY OF SOIL AND GROUNDWATER ANALYTICAL METHODS
SEPTEMBER 1994
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

Analyte	Method	Field (F) or Fixed-Base Laboratory (L)
GROUNDWATER		
Oxidation\Reduction Potential	Direct Reading Meter	F
Dissolved Oxygen	Direct Reading Meter	F
Temperature	Direct Reading Meter	F
pH	Direct Reading Meter	F
Manganese	Colorimetric, Hach Method 8034	F
Ferrous Iron (Fe ²⁺)	Colorimetric, Hach Method 8146	F
Carbon Dioxide	Titrimetric, Hach Method 1436-01	F
Alkalinity (Carbonate [CO ₃ ²⁻] and Bicarbonate [HCO ₃ ⁻])	Titrimetric, Hach Method 8221	F
Conductivity	EPA Method 120.1 ^{a/}	L
Nitrate + Nitrite	EPA Method 353.1	L
Chlorides	Waters Capillary Electrophoresis Method N-601	L
Sulfate	Waters Capillary Electrophoresis Method N-601	L
Methane and Ethene BTEX, TMBs, and	RSKSOP-147/175 ^{b/}	L
Total Fuel Carbon ^{c/}	RSKSOP-133	L
Volatile Organic Compounds	RSKSOP-148	L
Total Organic Carbon	RSKSOP-102	L
Phenols and aliphatic/aromatic acids	RSKSOP-177	
SOIL		
Total Fuel Carbon	RSKSOP-72 (Revision 1)	L
BTEX and TMBs	RSKSOP-124	L
TCE and PCE ^{d/}	RSKSOP-124	L
Total Organic Carbon	RSKSOP-102 and RSKSOP-120	L

^{a/} EPA = US Environmental Protection Agency.

^{b/} RSKSOP = Robert S. Kerr Laboratory (now known as NRMRL) standard operating procedure.

^{c/} BTEX = benzene, toluene, ethylbenzene, and xylenes; TMBs = trimethylbenzenes.

^{d/} TCE = trichloroethene; PCE = tetrachloroethene.

motor-vehicle and drilling rig operations. At one location (ESMW-10), shallow and deep well casings were placed in the same borehole to expedite drilling operations in unstable soil at this location. Detailed well installation procedures are described in the following paragraphs. Well completion diagrams are included in Appendix A.

2.1.3.1 Well Materials Decontamination

Well completion materials were inspected by the field hydrogeologist and determined to be clean and acceptable prior to use. All well completion materials were factory sealed. Pre-packaged casing, sand, bentonite, and concrete mix were used in well construction, and the bags were inspected for possible external contamination before use. Materials that could not be cleaned to the satisfaction of the field hydrogeologist were not used.

2.1.3.2 Well Casing

Upon completion of drilling or hand augering to the proper boring termination depth, a monitoring well casing was installed. Well construction details were noted on a Monitoring Well Installation Record form. This information became part of the permanent field record for the site. Monitoring well installation forms for the Upper Naknek Site are presented in Appendix A.

Blank well casing was constructed of Schedule 40 polyvinyl chloride (PVC) with an ID of 2 inches. All well casing sections were flush threaded, and glued joints were not used. The casing at each well was fitted with a vented top cap constructed of the same type of material as the well casing.

The field hydrogeologist verified and recorded the boring depth, the lengths of all casing sections, and the depth to the top of all well completion materials placed in the annulus between the casing and borehole wall. All lengths and depths were measured to the nearest 0.1 foot.

2.1.3.3 Well Screen

Well screens were constructed of flush-threaded, Schedule 40 PVC with an ID of 2 inches. The screens were factory slotted with 0.010-inch openings. Each shallow well was screened so that seasonal fluctuations of the water table can be measured and so that mobile LNAPL (if present) can be detected. Well screen positions were selected by the field hydrogeologist after consideration was given to the geometry and hydraulic characteristics of the stratum in which the wells were screened.

2.1.3.4 Sand Filter Pack

A graded sand filter was placed around the screened interval from the bottom of the casing to approximately 2 feet above the top of the screen. Number 10-20 Colorado silica sand was used for the sand filter pack. In the case of hand-augered boreholes in the wetland area (ESMW-9A, ESMW-11A, and ESMW-12A), immediate cave-in occurred in the boreholes because of highly saturated soils. A graded sand filter was placed at these locations only when possible; otherwise, no sand filter pack was placed around the screens.

2.1.3.5 Annular Sealant

A filter pack seal of sodium bentonite chips was placed above the sand pack in all wells, with the exception of temporary monitoring wells ESMW-9A, ESMW-11A, and ESMW-12A which were located in saturated wetland soils. The filter pack seal on all other wells was a minimum of 2 feet thick and, where placed above the water table, was hydrated in place with potable water. The filter pack seal was extended from the sand pack to the surface in all wells to better support for the protective casing. At ESMW-9A, ESMW-11A, and ESMW-12A, the screened intervals were near, or above, the ground surface, and sufficient sealing of the wells from surface waters was not possible. Thus, bentonite seals were not installed in these three wells. Adequate well development and purging (Sections 2.1.4 and 2.2.3.1.3) was performed on these wells to ensure that representative groundwater samples were collected.

For both shallow and deep wells, protective casings were set into the upper 2 to 2.5 feet of the annular seal. The casings were not cemented in place in order to minimize frost heave damage. Use of such a seal reduces the potential of frost heave damage because bentonite remains plastic at low temperatures, minimizing shear between the annular seal, the surrounding earth, and the protective casing. Pure sodium bentonite has a permeability low enough to provide a sufficient borehole seal. To minimize dehydration and protect the bentonite, a 6-inch-thick gravel pad was placed on top of the seal surrounding the protector casing.

2.1.3.6 Protective Cover

Each monitoring well was completed with a 6-inch by 6-inch aboveground protective cover with a locking cap. The covers were placed approximately 3 feet above grade, with a gravel pad surrounding the cover. Well identification numbers were permanently affixed to the well casings by stamping the well identification number onto the protective cover with a set of dies.

2.1.4 Well Development

Before being sampled, newly installed monitoring wells were developed. Well development removes sediment from inside the well casing and flushes fines, cuttings, and drilling fluids from the sand pack and the portion of the formation adjacent to the well screen.

Well development in most wells was accomplished using an inertial pump. The upward inertial flow of water was created by a rapid upward/downward movement of the development tubing, which was connected to the crankshaft of a small 3-horsepower engine. Water was prevented from leaving the downhole end of the tube by a Waterra® inertial ball valve. The movement of the development tubing and pump ball valve in the well created agitation in the casing that facilitated removal of fines from the monitoring well. All well development waters were collected in 55-gallon steel drums and transported to the decontamination pad for water conditioning through GAC and then disposal (see Section 2.1.2.2). All ball valves and tubing were decontaminated by steam-cleaning between well development periods.

Monitoring wells ESMW-9A, ESMW-11A, and ESMW-12A were developed using disposable polyethylene bailers. These monitoring wells were bailed until at least 10 well volumes were removed or until the well went dry. Wells that dried up were allowed to reequilibrate for 24 hours, and then the development process was continued until enough water was purged to collect a sample.

2.2 GROUNDWATER SAMPLING

This section describes the procedures used for collecting groundwater quality samples. In order to maintain a high degree of quality control (QC) during this sampling event, the procedures described in the site work plan (Engineering-Science, Inc., 1994), and summarized in the following sections, were followed.

Groundwater sampling occurred during September 1994, and consisted of collecting groundwater samples from new and existing monitoring wells. Personnel from Parsons ES and EPA RSKERL participated in groundwater sampling. EPA RSKERL was responsible for sample analysis. The procedures used to sample groundwater monitoring wells is described in Section 2.2.3.2.

Activities that occurred during groundwater sampling are summarized below:

- Assembly and preparation of equipment and supplies;
- Inspection of the well integrity, including
 - Protective cover, cap and lock,
 - External surface seal and pad,
 - Well casing, cap, and datum reference, and
 - Internal surface seal;
- Groundwater sampling, including
 - Water level measurements,
 - Visual inspection of water,
 - Well casing evacuation, and
 - Sampling;
- Sample preservation and packaging, including
 - Sample preparation,
 - Onsite measurement of physical parameters, and
 - Sample labeling;

- Completion of sampling records; and
- Sample delivery to the EPA Mobile Laboratory.

Detailed groundwater sampling and sample handling procedures that were used are presented in following sections.

2.2.1 Groundwater Sampling Locations

Groundwater samples were collected from existing and newly installed monitoring wells by Parsons ES and EPA RSKERL personnel. Eleven new monitoring wells, including three nested well pairs, were installed at the locations shown on Figure 2.1. After completion of well installation and development activities, these wells were sampled using a peristaltic pump with dedicated polyethylene tubing. Eighteen previously existing monitoring wells also were sampled under this program. Existing wells that were sampled included 500, 501, 506, 507, 508, 509, MW-50, MW-51, MW-52, MW-53, MW-60, MW-88, MW-89, MW-90, MW-91, WP-1, WP-2, and WP-3. Well completion data for the newly installed and previously installed wells are provided in Table 2.1. Field and laboratory analytical parameters are listed in Table 2.2, and a summary of field activities is listed in Table 2.3.

2.2.2 Preparation for Sampling

All equipment used for sampling was assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record-keeping materials were gathered prior to leaving the office.

2.2.2.1 Equipment Cleaning

All portions of sampling and test equipment that contacted the sample were thoroughly cleaned before use. This equipment included the water level probe and cable, lifting lines, test equipment for onsite use, and other equipment that contacted the samples. The following cleaning protocol was used:

- Cleaned with potable water and phosphate-free laboratory detergent;
- Rinsed with potable water;
- Rinsed with distilled or deionized water;
- Rinsed with reagent-grade acetone; and,
- Air dried prior to use.

Any deviations from these procedures were documented in a field notebook and on the groundwater sampling form.

TABLE 2.3
SUMMARY OF TREATABILITY STUDY ACTIVITIES
SEPTEMBER 1994
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

Location	Monitoring Well Installation	Slug Test Analysis	Soil Analyses		Groundwater Sample Date	Water Level Measurement	Volatile Organic Compounds	Fuel Hydrocarbons and Fuel Carbon	Total Organic Carbon	Groundwater Analyses						
			Total Organic Carbon	BTEX, TMBs, TCE, and PCE ^a Analysis						Well Head Analyses ^b	Mobile Lab Analyses ^c	Methane, ethane, and ethene	Chlorides	Nitrate + Nitrite (as Nitrogen)	Sulfate	Specific Conductivity
ES-MW08A	X ^d			X	9/22/94	X		X	X	X	X	X	X	X	X	X
ES-MW08B	X	X	X	X	9/22/94	X		X	X	X	X	X	X	X	X	X
ES-MW09A	X				9/22/94	X		X	X							
ES-MW10A	X		X	X	9/22/94	X		X	X	X	X	X	X	X	X	X
ES-MW10B	X				9/22/94	X		X	X	X	X	X	X	X	X	X
ES-MW11A	X					X										
ES-MW12A	X				9/20/94	X		X	X	X	X	X	X	X	X	X
ES-MW13A	X		X		9/23/94	X		X	X	X	X	X	X	X	X	X
ES-MW14A	X				9/23/94	X		X	X	X	X	X	X	X	X	X
ES-MW15A	X				9/22/94	X		X	X	X	X	X	X	X	X	X
ES-MW15B	X				9/22/94	X		X	X	X	X	X	X	X	X	X
MW50					9/17/94	X		X	X	X	X	X	X	X	X	X
MW51					9/16/94	X		X	X	X	X	X	X	X	X	X
MW52					9/17/94	X		X	X	X	X	X	X	X	X	X
MW53					9/17/94	X		X	X	X	X	X	X	X	X	X
MW54						X										
MW-55						X										
MW57						X										
MW58						X										
MW60					9/17/94	X		X	X	X	X		X	X	X	X
MW61						X										
MW88					9/16/94	X		X	X	X	X		X	X	X	X
MW89					9/16/94	X		X	X	X	X		X	X	X	X
MW90					9/16/94	X		X	X	X	X		X	X	X	X
MW91					9/20/94	X		X	X	X	X	X	X	X	X	X
WP1					9/19/94	X		X	X	X	X	X	X	X	X	X
WP2					9/19/94	X		X	X	X	X	X	X	X	X	X
WP3					9/19/94	X		X	X	X	X	X	X	X	X	X
500					9/16/94	X		X	X	X	X	X	X	X	X	X
501					9/16/94	X		X	X	X	X	X	X	X	X	X
506					9/22/94	X		X	X	X	X	X	X	X	X	X
507					9/22/94	X		X	X	X	X	X	X	X	X	X
508					9/20/94	X		X	X	X	X	X	X	X	X	X
509		X			9/17/94	X		X	X	X	X			X		

^a BTEX = benzene, toluene, ethylbenzene, and xylenes; TMBs = trimethylbenzenes; TCE = trichloroethene; and PCE = tetrachloroethene.

^b Well head analytical parameters included dissolved oxygen, reduction/oxidation potential, pH, and temperature.

^c Mobile laboratory analyses include total alkalinity, ferrous iron, manganese, and A17/carbon dioxide.

^d X indicates that the analysis was completed.

2.2.2.2 Equipment Calibration

As required, field analytical equipment was calibrated according to the manufacturers' specifications prior to field use. This requirement applied to equipment used for onsite chemical measurements of DO, pH, redox, and temperature.

2.2.3 Sampling Procedures

Special care was taken to prevent contamination of the groundwater and extracted samples through cross contamination from improperly cleaned equipment. Water level probes and cable used to determine static water levels and well total depths were thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 2.2.2.1. In addition, a clean pair of new, disposable nitrile gloves was worn each time a different well was sampled.

2.2.3.1 Groundwater Monitoring Well Sampling

2.2.3.1.1 Preparation of Location

Prior to starting the sampling procedure, the area around the well was cleared of foreign materials, such as brush, rocks, and debris. These procedures prevented sampling equipment from inadvertently contacting debris around the monitoring well.

2.2.3.1.2 Water Level and Total Depth Measurements

Prior to removing any water from the well the static water level was measured. An electrical water level probe was used to measure the depth to groundwater below the well datum to the nearest 0.01 foot. After measurement of the static water level, the water level probe was lowered to the bottom of the well for measurement of total well depth (recorded to the nearest 0.01 foot). Based on these measurements, the volume of water to be purged from the wells was calculated.

2.2.3.1.3 Well Purging

Where possible, three times the calculated casing volume was removed from each well prior to sampling; however, most wells located in the shallow soils of the wetland (ESMW-9A, ESMW-11A, and ESMW-12A) were purged dry. All purge water was placed in 55-gallon steel drums and transported to the temporary decontamination pad used for steam-cleaning of augers. Purge water was conditioned with GAC, collected in a 500 gallon tank, and later disposed of in the KSA sanitary sewer.

2.2.3.1.4 Sample Extraction

A peristaltic pump with dedicated polyethylene tubing was used to extract groundwater samples from the well. The sample was transferred directly into the appropriate sample container. The water was carefully poured down the inner walls of the sample bottle to minimize aeration of the sample. Sample bottles for BTEX and TMB analysis were filled so that there was no headspace or air bubbles within the container.

2.2.4 Onsite Chemical Parameter Measurement

2.2.4.1 Dissolved Oxygen Measurements

DO measurements were taken using an Orion® model 840 DO meter in a flow-through cell at the outlet of the peristaltic pump. DO concentrations were recorded after the readings stabilized, and in all cases represent the lowest DO concentration observed.

2.2.4.2 pH, Redox, and Temperature Measurements

Because the pH, redox, and temperature of the groundwater change significantly within a short time following sample acquisition, these parameters were measured both in the field and at the EPA Mobile Laboratory as soon as possible after acquisition. The measurements were made in a clean glass container separate from those intended for laboratory analysis, and the measured values were recorded in the groundwater sampling record.

2.2.5 Sample Handling

2.2.5.1 Sample Preservation

The EPA Mobile Laboratory added any necessary chemical preservatives to sample containers prior to collection of samples.

2.2.5.2 Sample Container and Labels

Sample containers and appropriate container lids were provided by the USEPA Mobile Laboratory. The sample containers were filled as described in Sections 2.2.3.1.4, and the container lids were tightly closed. The sample label was firmly attached to the container side, and the following information was legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (groundwater);
- Sampling date;
- Sampling time;
- Preservatives added; and,
- Sample collector's initials.

2.2.5.3 Sample Shipment

After the samples were sealed and labeled, they were packaged for transport to the onsite EPA Mobile Laboratory. The following packaging and labeling procedures were followed:

- Sample was packaged to prevent leakage or vaporization from its container;
- Shipping container was labeled with
 - Sample collector's name, address, and telephone number;
 - Description of sample;
 - Quantity of sample; and,
 - Date of shipment.

The packaged samples were hand-delivered to the EPA Mobile Laboratory. Delivery occurred shortly after sample acquisition.

2.3 AQUIFER TESTING

Slug tests were conducted to estimate the hydraulic conductivity of the shallow saturated zone at the Upper Naknek Site. Slug tests are single-well hydraulic tests used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. The hydraulic conductivity values determined from these slug tests (and the Bouwer and Rice methods, see below) are representative of a relatively small vertical section of the aquifer, because flow into the well screen is predominantly horizontal. This approach is deemed adequate at this site given the known nature of the saturated zones underlying the site. Specifically, because the site is underlain by a relatively thin, shallow unconfined aquifer, the hydraulic conductivity values determined from most of the shallow groundwater wells will be representative of this zone. Slug tests were performed in monitoring wells ESMW-8A and 8B, ESMW-15A and 15B, and ESMW-14A (Figure 2.1). Detailed slug testing procedures are presented in the *Draft Technical Protocol for Implementing the Intrinsic Remediation with Long-Term Monitoring Option for Natural Attenuation of Dissolved-Phase Fuel Contamination in Groundwater* (Wiedemeier *et al.*, 1994), hereafter referred to as the Technical Protocol document.

2.3.1 Slug Test Data Analysis

Data obtained during slug testing were analyzed using AQTESOLV software and the methods of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions. The results of slug testing are presented in Section 3.3.

2.4 SURVEYING

After the field work described herein was concluded, a third order survey of all new monitoring well locations and elevations was completed by a professional land surveyor. The horizontal locations were measured relative to existing monitoring wells. Vertical location of the ground surface adjacent to the well casing and the measurement datum (top of the PVC well casing) were measured relative to existing wells tied to a US Geological Survey (USGS) mean sea level (msl) datum. Horizontal location was surveyed to the nearest 0.1 foot. Datum and ground surface elevations were surveyed to the nearest 0.01 foot. Horizontal control was based on a USGS benchmark on the west end of the east-west runway at KSA.

SECTION 3

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This section incorporates data collected during investigations as summarized by SAIC (1993b) and EMCON (1994a) and more recent investigations conducted by Parsons ES in conjunction with researchers from EPA RSKERL in September 1994. Investigative techniques used by Parsons ES and RSKERL researchers to determine the physical characteristics of the Upper Naknek Site are discussed in Section 2.

3.1 SURFACE FEATURES

3.1.1 Topography and Surface Water Hydrology

The Upper Naknek Site is situated in the Nushagak-Bristol Bay Lowland, an area with little vertical relief. The general grade of the land surface is modest as it slopes toward the Naknek River, which is approximately 1,500 feet to the south. A natural wetland and a stretch of subarctic forest separate the Upper and the Lower Naknek Sites (Figure 1.4). The Upper Naknek Site is situated on a manmade bluff overlooking the wetland. This bluff is approximately 15 feet in height and runs east/west along the southern border of the Upper Naknek Site. At the base of the bluff, groundwater is present at or near the land surface, defining the beginning of the wetland. The wetland is an intermediate recharge or discharge point for groundwater in the surface aquifer. The Naknek River is the ultimate discharge point for groundwater in the surface aquifer. Besides the Naknek River and the natural wetland, no other natural surface water bodies exist in the immediate vicinity of the study area.

3.1.2 Manmade Features

The Upper Naknek Site is characterized by unpaved roads and temporary structures serving as pump houses for fueling operations. Surface cover at the site consists mostly of unpaved ground devoid of vegetation. Trees, bushes, and grass surround the perimeter of the site; however, the rest of the Upper Naknek site has been cleared of natural vegetation and obstacles. A north/south road connects the Upper Naknek Site with the Lower Naknek Site. A culvert beneath the north/south road is a flow path between the Upper Naknek wetland and wetland terrain to the east.

Several restricted areas at the site are protected with 8-foot high security fencing. These restricted areas surround pump houses and UST locations. Former Landfill No. 5 exists in the western portion of the Upper Naknek site and is characterized by small surface windrows and earthen piles created from earthmoving operations. This landfill was identified by an earlier geophysics survey (CH₂M Hill, 1989), which indicated buried material on the western side of the Upper Naknek Site. A drum shredding operation

located in the central portion of the Upper Naknek Site contains shredded steel barrels stacked in a fenced pile extending as much as 10 feet below the ground surface (bgs) and as high as 30 feet above the ground surface. Immediately north of the shredded drum pile is a small soil farm operation for which the frequency of use is not known. A french drain is located in the lower central part of the Upper Naknek Site. The surface of this french drain consists of medium gravel extending down the sideslope of the east-west bluff and approximately 20 feet into the wetland area.

3.1.3 Climate

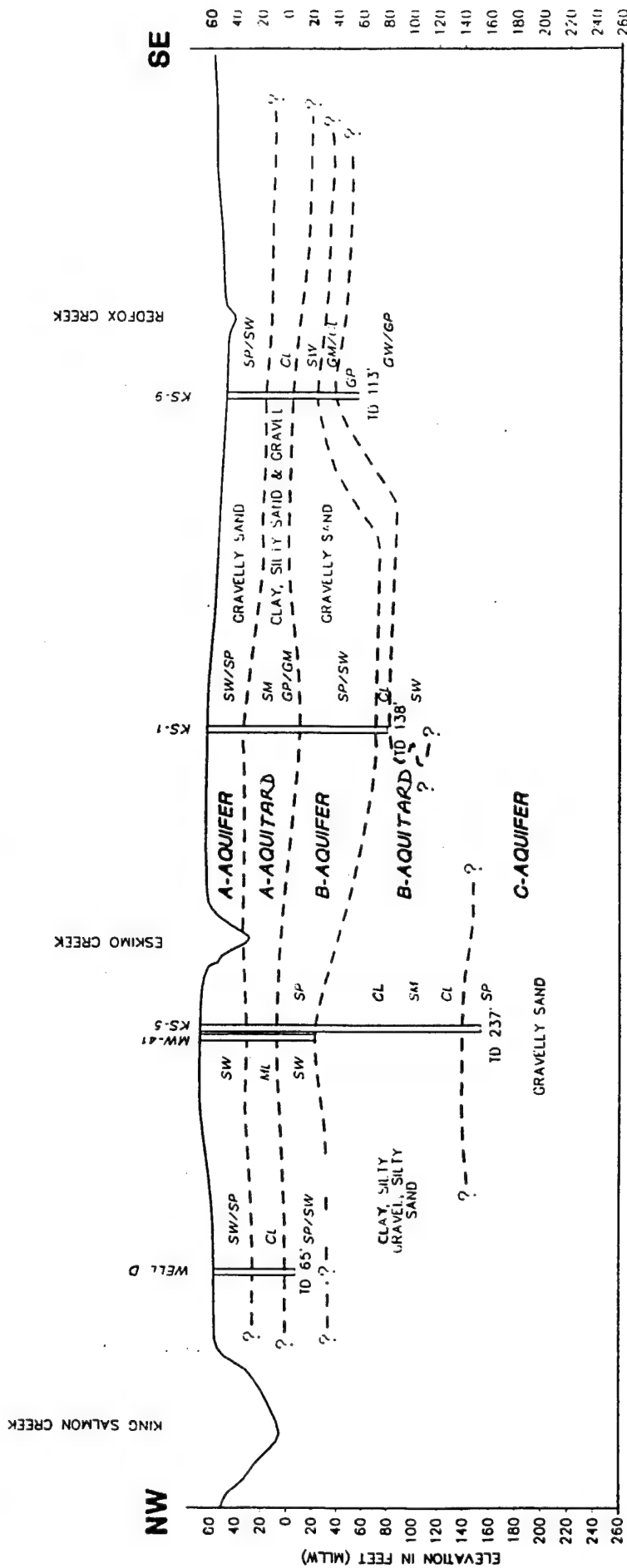
The King Salmon area experiences a transitional climate between the continental temperature extremes encountered in interior Alaska, and the milder coastal maritime climate. Mean annual temperature is 33 degrees Fahrenheit (°F), with a recorded range of minus 46°F in January to 88°F in June. Mean annual precipitation is approximately 20 inches. Most rainfall occurs in late summer and fall. Snowfall averages 46 inches per year, with a monthly recorded maximum of 20 inches in March. Discontinuous permafrost may be encountered in the KSA area, with known occurrences east of the Upper Naknek area at Eskimo Creek and in the wetlands west of the Eskimo Creek/Naknek River confluence (Figure 1.3).

3.2 REGIONAL GEOLOGY AND HYDROGEOLOGY

King Salmon is situated on a segmented volcanic arc of the Aleutian arc-trench system. This arc-trench system continues to form along the collision boundary between the northward-moving Pacific tectonic plate as it is subducted beneath the west/southwest-moving North American tectonic plate. Hence, the entire Alaska-Aleutian peninsula is an intensively active seismic zone. Within the eastern Aleutian arc, 10 of 22 volcanoes spanning the 336-mile-long volcanic front have erupted in recorded history, and another 6 exhibit signs of hydrothermal activity. The rugged mountain peaks along the southeastern coast of the Alaskan Peninsula are the surface manifestation of volcanic rocks and distributed sediments from earlier, arc-related volcanoes. The lowland areas of the Alaskan Peninsula are generally mantled by Tertiary volcanic rock that has a low resistance to erosion, which contributes to the subdued topographic expression of the Nushagak-Bristol Bay Lowland.

The upper few hundred feet of unconsolidated soils in the KSA area consist of glacially deposited Tertiary sediments. The deposits have been reworked by marine tidal, fluvial, and lacustrine processes, and include clay, silt, and sand. In general, three aquifers exist in the vicinity of KSA. The aquifers consist of unconsolidated well to poorly sorted, silty and gravely sands separated by aquitards (confining layers) consisting of silty and clayey gravels, silty sands, silts, and clays. A generalized cross-section of the area is shown in Figure 3.1.

The shallowest aquifer, the "A-Aquifer", is unconfined and exposed at the surface in nearly all locations at KSA. This aquifer is made up of moderately well-sorted sands and silty sands with discontinuous lenses of medium- to coarse-grained gravel at the base. Static water level varies from the ground surface in creeks and wetlands to as much as 30 feet bgs on the northern side of KSA. Discontinuous permafrost may locally act as an impermeable barrier to the flow of groundwater. The A-aquifer is likely recharged by



EXPLANATION

KS	KING SALMON AIRPORT BASE PRODUCTION WELL
MW	MONITORING WELL
TD	TOTAL DEPTH
CL	UNIFIED SOIL CLASSIFICATION SYMBOL

FIGURE 3.1

GENERALIZED HYDROGEOLOGIC CROSS-SECTION FOR KING SALMON AIRPORT

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska



**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

Source: Emcon, 1994a.

M:\45011\DRAWINGS\SS12\95DN0091

LAYER 3-1

precipitation and influent stream flow. The general flow pattern of groundwater is toward topographically lower areas, streams, and wetlands.

Underlying the A-Aquifer is a zone of lower hydraulic conductivity consisting of gravely, clayey silt and sandy silt. This unit is called the "A-Aquitard." The aquitard varies from 7 to 22 feet thick, and was previously reported to locally disrupt and modify the regional unconfined groundwater flow pattern for the A-Aquifer, especially in areas where the aquitard is thickest (SAIC, 1993b).

Below the A-Aquitard is the "B-Aquifer." The top of the B-Aquifer is present between 25 and 80 feet bgs at KSA. The B-Aquifer is suspected to be a semiconfined aquifer and consists of interbedded sequences of silty sands, sandy gravels, and silty to sandy gravels. The potentiometric surface of the B-Aquifer in some wells is close to the A-Aquifer water table elevation in the same or neighboring wells. Groundwater movement in the B-Aquifer is generally to the south.

Between the B-Aquifer and the underlying aquifer is a second aquitard called the "B-Aquitard." This second aquitard is estimated to be between 10 and 120 feet thick and consists mostly of sandy clay.

Limited data are available concerning the third water-bearing unit at the site, the C-Aquifer. The C-Aquifer underlies the B-Aquitard at approximately 200 feet bgs. This aquifer also is suspected of being confined. KSA water supply wells are completed in the C-Aquifer. The thickness of the C-aquifer is unknown, but data from water supply well No. 5 at KSA indicate that it may be up to 20 feet thick. No data are available concerning the direction of groundwater flow in the C-Aquifer.

3.3 SITE GEOLOGY AND HYDROGEOLOGY

Characterization of the vadose zone and shallow aquifer system at the Upper Naknek Site has been the objective of several investigations. Prior to this investigation, at least 14 soil borings and 16 groundwater monitoring wells from three independent investigations have been completed in the vicinity of the Upper Naknek Site and in the vicinity of the hydrocarbon plumes emanating from that area. During September 1994, Parson ES, in conjunction with researchers from the RSKERL, drilled or hand augered eight soil borings in which groundwater monitoring wells were installed. Monitoring wells installed in these borings are designated as ESMW-8A, ESMW-8B, ESMW-9A, ESMW-10A, ESMW-10B, ESMW-11A, ESMW-12A, ESMW-13A, ESMW-14A, ESMW-15A, and ESMW-15B. Borehole depths ranged from 3 to 21 feet bgs. Figure 2.1 shows the locations of these wells, and Table 2.1 presents available monitoring well and piezometer completion information and groundwater elevations.

3.3.1 Lithology and Stratigraphic Relationships

The glacial sediments of the surface aquifer at the Upper Naknek Site mostly consist of very-fine- to medium-grained (occasionally coarse) silty sands. The A-aquitard (separating the A-aquifer from the B-aquifer) at the site is mostly made up of gravely and sandy clays. The top of the A-aquitard is estimated to be about 15 feet bgs in the wetland areas south of the Upper Naknek Site and between 25 to 30 feet bgs on the bluff of the Upper Naknek Site. Soils encountered during drilling operations on the bluff at the

Upper Naknek Site for wells ESMW-8 and ESMW-15 showed signs of fill material on the surface underlain by a large interval of homogeneous sand. This homogeneous sand layer was present up to 22 feet bgs, where evidence of the A-Aquitard was encountered. Personal communication with drillers who have worked in the KSA area suggests that the less permeable layers of clays and silts of the A-Aquitard are typically overlain by zones of pebbles and gravel. Although the A-Aquitard was not definitely observed in soil borings ESMW-8 and ESMW-15, sandy gravel with pebbles and pebbly silt with sand were seen from borehole samples at 18 and 22 feet bgs, respectively. No stringers of clay or other significant soil heterogeneities were encountered above the surface of the A-Aquitard.

Soil conditions immediately south of the east/west bluff and monitoring well locations ESMW-8 and ESMW-15 change to a wetland-type soil stratigraphy. The surface of the wetland was characterized by long-leaf grasses and mounds of deep-rooted foliage. Beneath the vegetation was up to 1 foot of dark brown peat. Below the peat, the expected sandy interval of the A-Aquifer was present. Some thin intervals of clay and silty sand were also observed. Frozen soil at 3.5 to 7 feet bgs in the wetland stopped further hand-augering activities at ESMW-9A and ESMW-11A. Soil borehole ESMW-10 was the deepest drilled in the wetland with a HSA (14 feet bgs). With the exception of a 1.5-foot zone of gravel, sand, and cobble material, only fine to medium grained sand was encountered at depth at ESMW-10. Soil borehole data therefore suggest that the wetland area consists of thin layers of sand (3.5 to 7 feet thick) bounded at depth by impermeable, frozen layers of soil which are not necessarily part of the lower confining A-Aquitard.

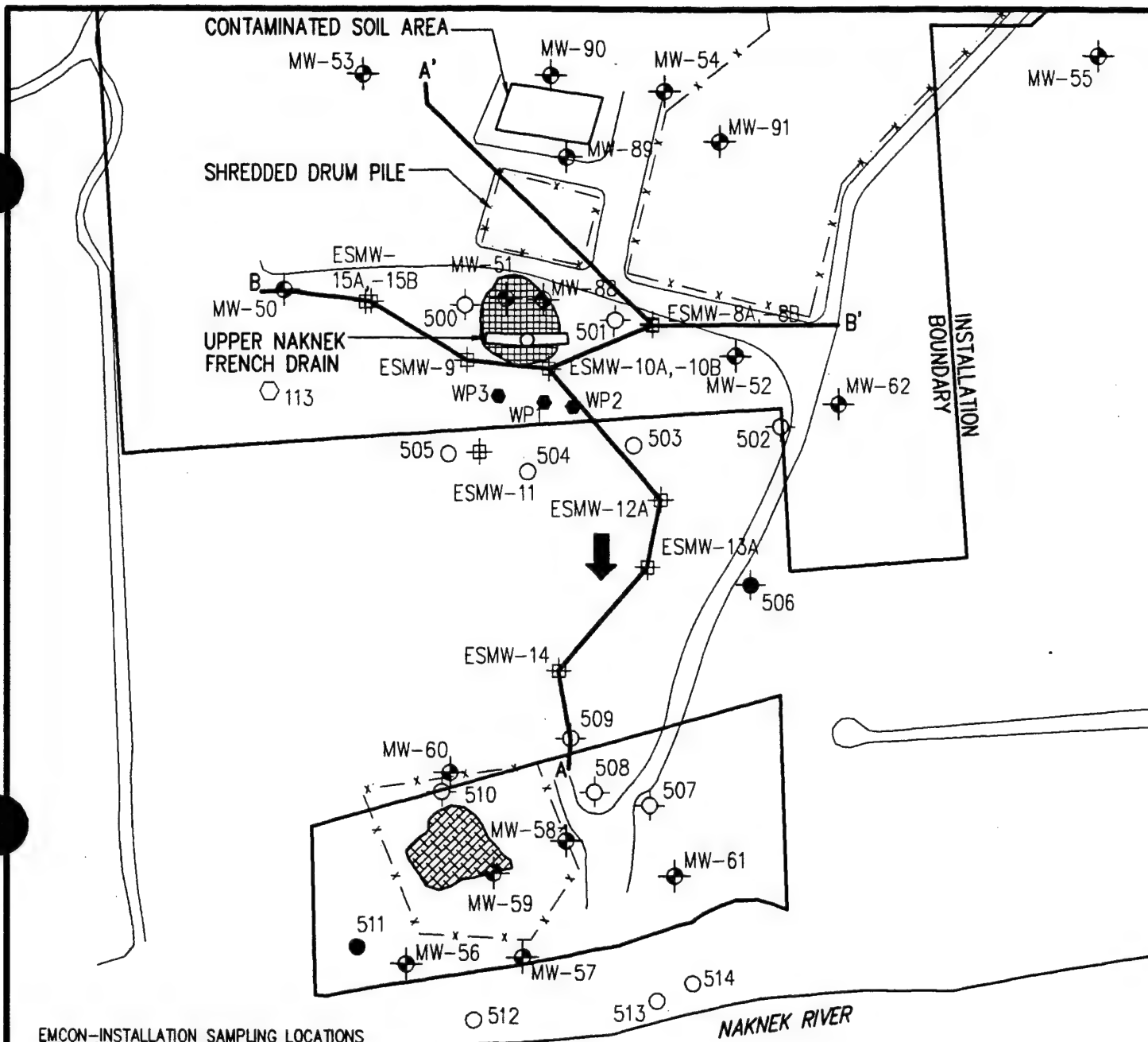
Soils immediately south of the wetland were explored with soil borings ESMW-13A and ESMW-14A. The surface of the A-Aquitard was found at 9 feet bgs at ESMW-13A, and at 14 feet bgs at ESMW-14A. Frozen soil in the sandy zone of the aquifer was not evident during drilling, and the saturated zone in this portion of the A-Aquifer appears thicker than in the wetland area. Previous soil data for wells 509 and 510 showed that fine to medium sands with occasional coarse and silty sands of the A-Aquifer extend to the edge of the Naknek river. Through this area, the top of the A-Aquitard is believed to average 15 feet bgs.

These stratigraphic relationships are illustrated by hydrogeologic sections A-A' and B-B', which include data from previously installed wells and borings and newly installed wells. Figure 3.2 shows the locations of these sections. Figure 3.3 shows hydrogeologic section A-A', which is approximately parallel to the groundwater flow direction. Figure 3.4 presents hydrogeologic section B-B', which is approximately perpendicular to the direction of groundwater flow.

3.3.2 Groundwater Hydraulics

3.3.2.1 Flow Direction and Gradient

Shallow groundwater at the Upper Naknek Site generally flows to the south. Depending on location-specific heterogeneities in the A-Aquifer, the groundwater locally flows southeast or southwest, as indicated by contours near the french drain and the Lower Naknek area (Figure 3.5). Depth to groundwater varies from 0 to 16 feet bgs in the vicinity of the Upper Naknek Site, and is greatest in upgradient, or northern portions of the site (approximately 16 feet bgs). Groundwater depths of 0 feet bgs (i.e., the water



EMCON-INSTALLATION SAMPLING LOCATIONS

- 504 ○ SEDIMENT/SURFACE WATER SAMPLE PAIR
- 113 ○ WELL POINT (LF1)
- 507 ○ A-AQUIFER MONITORING WELL
- 506 ● B-AQUIFER MONITORING WELL
- ➔ GROUNDWATER FLOW DIRECTION
- FENCE

SAMPLING LOCATIONS INSTALLED PRIOR TO FALL 1993

- MW-54 ● MONITORING WELL
- WP3 ● WELL POINT

SAMPLING LOCATIONS INSTALLED SEPTEMBER 1994

- ESMW-12A ● MONITORING WELL
- ▨ AREA EXCAVATED IN 1992
- ▩ FORMER PRODUCT SEEP
- A—A' HYDROGEOLOGIC CROSS-SECTION



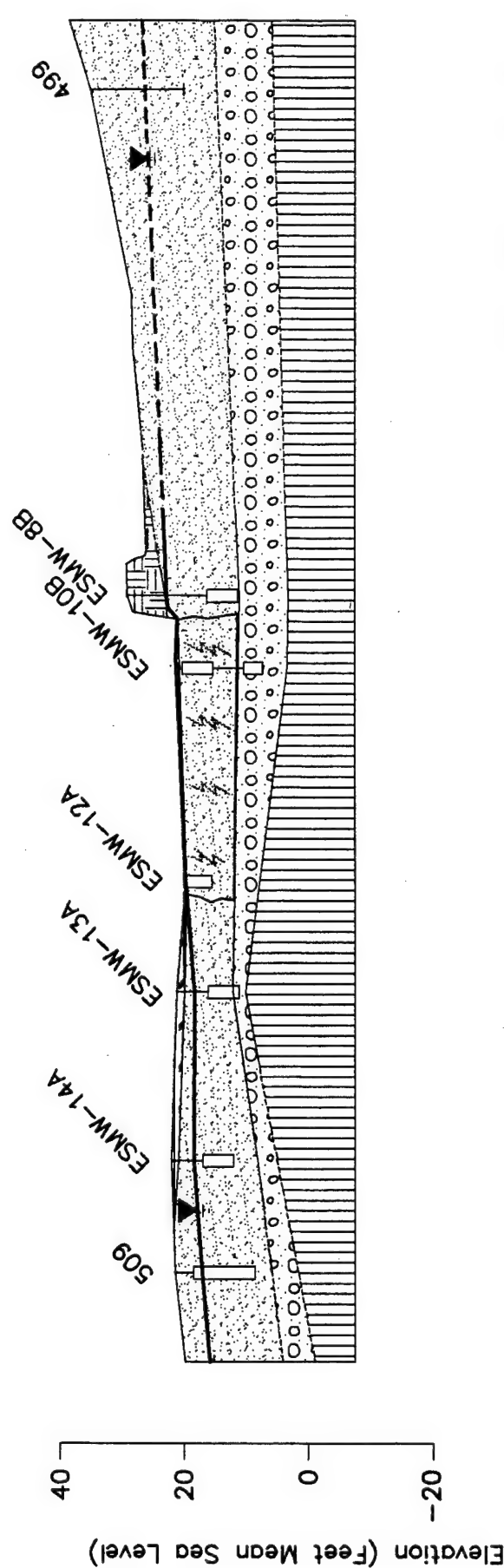
FIGURE 3.2
LOCATION OF
HYDROGEOLOGIC
CROSS-SECTIONS

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS
ENGINEERING SCIENCE, INC.
Denver, Colorado

SOUTH
A

NORTH
A'



LEGEND

- Contact
- Approximate Contact
- Well Identification
- Well Screen
- Bottom of Borehole
- Approximate Location of Water Table (Dashed where Inferred)

Area of intermittent frozen soil

Brown sandy silt to silty sand FILL.
Organic matter present.

Dark brown PEAT. Often frozen near ground surface.

Brown to grey, fine- to medium-grained SAND.

Brown, silty, sandy GRAVEL. Some subrounded pebbles present.

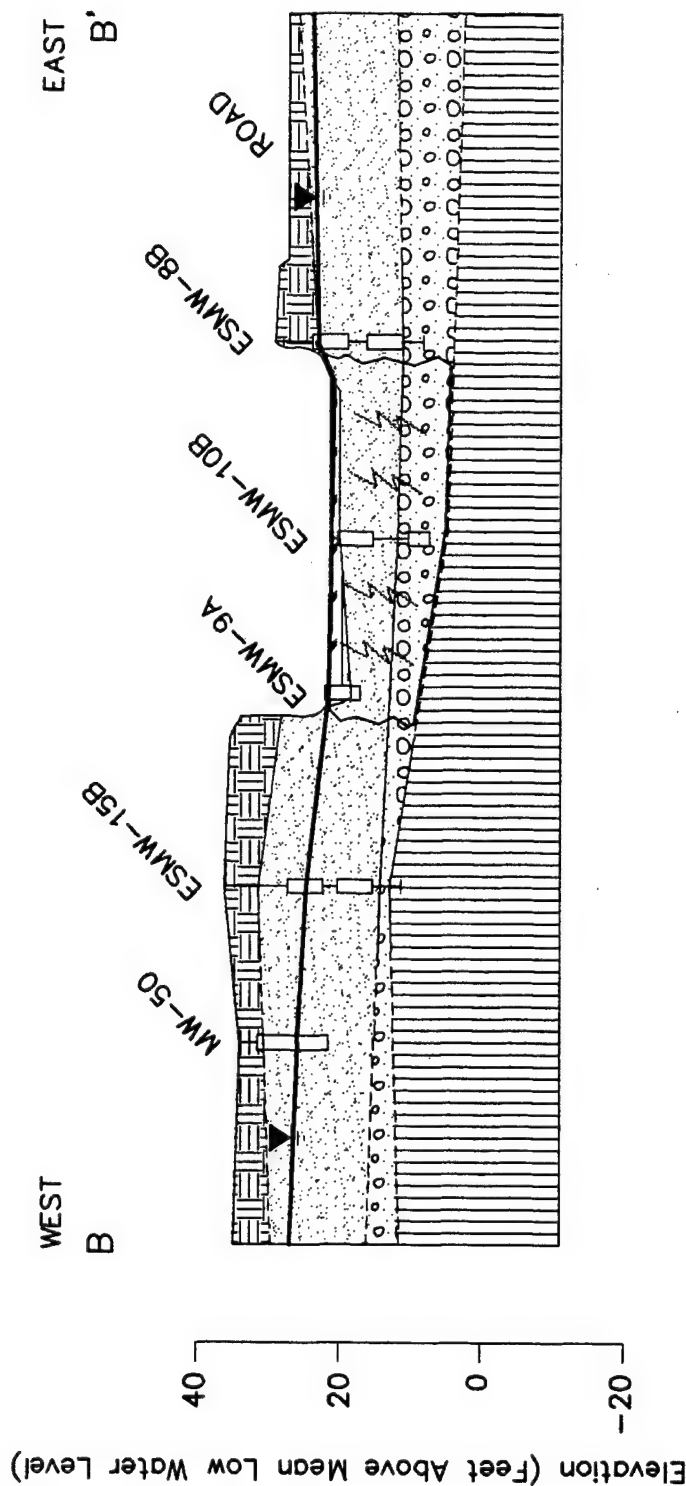
Grey, clayey SILT to silty CLAY. Dense and highly plastic. Brown sand lenses present.

FIGURE 3.3

HYDROGEOLOGIC CROSS-SECTION A-A'

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska

PARSONS
ENGINEERING SCIENCE, INC.
Denver, Colorado



VERTICAL EXAGGERATION 7.5x
0 200 400
FEET

FIGURE 3.4

HYDROGEOLOGIC CROSS-SECTION B-B'

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska



**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

- LEGEND**
- Contact
 - Approximate Contact
 - Well Identification
 - Well Screen
 - Bottom of Borehole
 - Approximate Location of Water Table
 - Area of intermittent frozen soil
 - Brown sandy silt to silty sand FILL. Organic matter present.
 - Dark brown PEAT. Often frozen near ground surface.
 - Brown to grey, fine- to medium-grained SAND.
 - Brown, silty, sandy GRAVEL. Some subrounded pebbles present.
 - Grey, clayey Silt to silty CLAY. Dense and highly plastic. Brown sand lenses present.

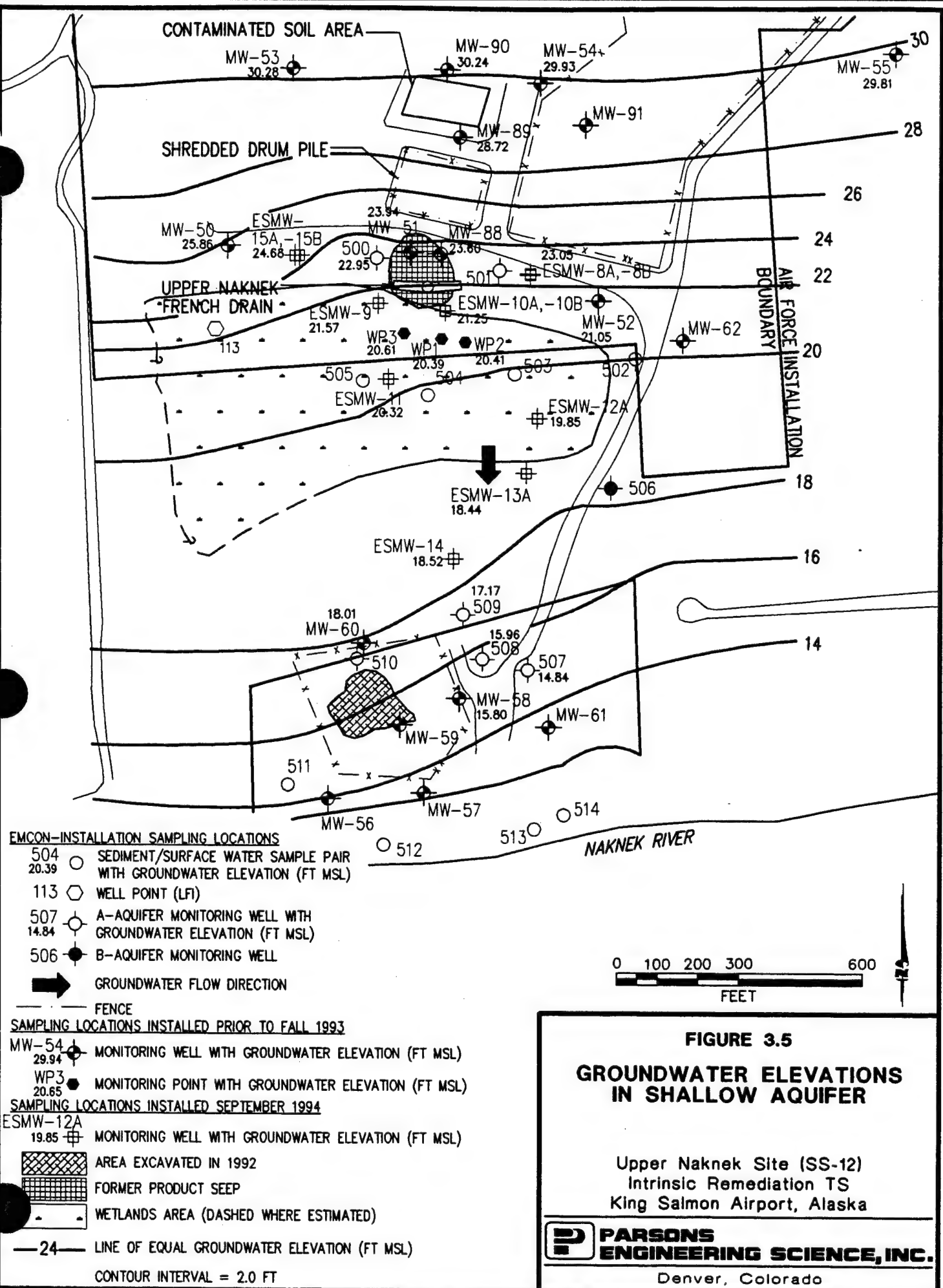


table intercepted the land surface) were observed only in the wetland. The change in elevation from the bluff area to the lower wetland area has a marked effect on groundwater gradients. Gradients were greater on the bluff [~ 0.02 (ft per ft)] as groundwater descended toward the wetland. In the vicinity of the wetland, groundwater gradients decreased to approximately 0.006 ft/ft. Table 3.1 presents groundwater elevation data collected in September 1994.

Approaching the Lower Naknek Site, depth to groundwater varies from 4 to 8 feet bgs. The gradient increases to approximately 0.01 ft/ft near the Naknek River. Groundwater from the A-Aquifer discharges as seeps along a second bluff along the Naknek River. Vertical gradients at the Upper Naknek Site were measured from the three nested monitoring well locations [ESMW-8(A and B); ESMW-10(A and B); and ESMW-15(A and B)]. Vertical gradients in these nested wells ranged from 0.0392 ft/ft to 0.0089 ft/ft downward. The downward gradient has distributed contaminants over the depth of the surface aquifer and possibly over the full saturated thickness (Section 4.3.1.1). Downward migration of BTEX contaminants dilutes contaminant concentrations and minimizes the potential for contamination of wetland sediments and surface waters downgradient of the site.

It appears, based on geologic and hydrogeologic information, including the presence of the wetland, that the shallow aquifer at the Upper and Lower Naknek areas is unconfined. It is possible that small clay and silt units locally cause confined conditions.

3.3.2.2 Hydraulic Conductivity

Slug tests were performed in early studies at KSA by CH₂M Hill (1990). Recorded hydraulic conductivities from these tests varied from 0.0104 feet per minute (ft/min) to 0.951 ft/min, with an average value of 0.243 ft/min. These values are a generalized range for the Upper Naknek Site as well as 10 other IRP sites at the base. More recent slug tests were performed by EMCON (1994c) at the Upper Naknek Site, but the data were unavailable at the time of this report.

Hydraulic conductivity was estimated at a well installed by Parsons ES and a previously installed well using rising head and falling head slug tests as described in Section 2. These slug test results are provided in Appendix A. Hydraulic conductivities measured at ESMW-8B were 0.026 ft/min and 0.030 ft/min, for an average of 0.028 ft/min. Hydraulic conductivities measured at monitoring well 508 were 0.025 and 0.020 ft/min, for an average of 0.022 ft/min. The two hydraulic conductivity values do not vary significantly and the average of the hydraulic conductivity values from wells ESMW-8B and 508 is 0.025 ft/min.

3.3.3.3 Effective Porosity

Because no effective porosity data are available for the Upper Naknek Site, accepted literature values for the type of soil making up the shallow saturated zone were used. Freeze and Cherry (1979) give a range of effective porosity for silt and sand of 0.25 to 0.50. To be conservative (lower effective porosity results in greater groundwater velocity), the effective porosity for sediments of the shallow saturated zone is assumed to be 0.25.

TABLE 3.1
WATER LEVEL ELEVATION DATA
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

Well Location	Date	Northing	Easting	Well ID (inches)	Datum Elevation (ft msl) ^{a/}	Ground Elevation (ft msl)	Total Depth to Water (ft bgs) ^{b/}	Total Depth to Water (ft btoc) ^{c/}	Elevation of Water Table (ft msl)
ESMW-8A	9/24/94	1714720.83	750058.14	2	32.29	29.15	6.10	9.24	23.05
ESMW-8B	9/24/94	1714717.78	750058.45	2	32.18	29.15	6.30	9.33	22.85
ESMW-9A	9/24/94	1714648.98	749690.77	2	25.50	21.61	0.04	3.93	21.57
ESMW-10A	9/24/94	1714630.73	749853.07	2	23.30	21.33	0.08	2.05	21.25
ESMW-10B	9/24/94	1714630.55	749852.60	2	24.18	21.33	0.08	2.93	21.25
ESMW-11A	9/24/94	1714466.90	749715.65	2	23.53	20.52	0.21	3.21	20.32
ESMW-12A	9/24/94	1714372.28	750075.50	2	23.46	NA ^{d/}	NA	3.61	19.85
ESMW-13A	9/24/94	1714239.65	750048.82	2	24.02	21.29	2.85	5.58	18.44
ESMW-14A	9/24/94	1714034.10	749874.14	2	25.04	22.17	3.65	6.52	18.52
ESMW-15A	9/24/94	1714763.18	749487.24	2	39.15	36.30	11.56	14.42	24.73
ESMW-15B	9/24/94	1714763.46	749497.86	2	39.00	36.30	11.60	14.31	24.69
500	9/24/94	1714756.56	749686.11	2	39.96	NA	NA	16.96	23.00
501	9/24/94	1714750.77	749937.57	2	NA	33.30	NA	12.62	NA
502	9/24/94	NA	NA	2	NA	20.30	NA	NA	NA
506 ^{e/}	9/24/94	1714205.22	750254.74	2	20.49	18.51	0.91	2.89	17.60
507	9/24/94	1713765.31	750054.77	2	19.22	16.89	2.05	4.38	14.84
508	9/24/94	1713791.01	749945.45	2	22.27	18.95	2.98	6.31	15.96
509	9/24/94	1713899.66	749898.95	2	24.29	21.52	4.35	7.12	17.17
510	9/24/94	NA	NA	2	NA	23.30	NA	NA	NA
MW-50	9/24/94	1714786.19	749323.67	2	35.63	34.05	8.19	9.77	25.86
MW-51	9/24/94	1714770.25	749488.43	2	33.74	32.57	8.63	9.80	23.94
MW-52	9/24/94	1714656.18	750223.58	2	25.74	24.39	3.34	4.69	21.05
MW-53	9/24/94	1715210.10	749482.68	2	45.15	43.81	13.53	14.87	30.28
MW-54	9/24/94	1715177.35	750080.86	2	43.81	42.16	12.22	13.87	29.94
MW-55	9/24/94	1715248.19	750946.95	2	44.55	43.06	13.25	14.74	29.81
MW-56	9/24/94	NA	NA	2	NA	17.00	NA	NA	NA
MW-57	9/24/94	1713498.45	749844.43	2	NA	17.86	NA	NA	NA
MW-58	9/24/94	1713694.49	749889.21	2	20.01	18.88	3.08	4.21	15.80
MW-59	9/24/94	NA	NA	2	NA	19.00	NA	NA	NA
MW-60	9/24/94	1713829.21	749657.07	2	25.41	24.42	6.41	7.40	18.01
MW-61	9/24/94	1713624.14	750104.32	2	19.33	19.33	NA	NA	NA
MW-62	9/24/94	NA	NA	2	NA	20.00	NA	NA	NA
MW-88	9/24/94	1714766.78	749842.40	2	36.02	34.01	10.36	12.38	23.64
MW-89	9/24/94	1715046.90	749888.56	4	38.16	37.26	8.54	9.44	28.72
MW-90	9/24/94	1715209.67	749856.27	4	46.44	44.46	14.22	16.20	30.24
MW-91	9/24/94	1715077.52	750191.76	4	40.68	38.08	NA	NA	NA
WP-1	9/24/94	1714563.42	749846.84	2	23.76	19.80	-0.59	3.37	20.39
WP-2	9/24/94	1714555.47	749902.60	2	24.33	20.38	-0.03	3.92	20.41
WP-3	9/24/94	1714576.10	749753.82	2	24.70	20.77	0.16	4.09	20.61

^{a/} ft msl = feet above mean sea level elevation.

^{b/} ft bgs = feet below ground surface.

^{c/} ft btoc = feet below top of casing.

^{d/} NA=Not Available.

^{e/} 506 is screened in the B-aquifer.

3.3.3.4 Advective Groundwater Velocity

The advective velocity of groundwater in the direction parallel to groundwater flow is given by:

$$\bar{v} = \frac{K}{n_e} \frac{dH}{dL}$$

Where: \bar{v} = Average advective groundwater velocity (seepage velocity) [L/T]

K = Hydraulic conductivity [L/T] (0.025 ft/min)

dH/dL = Gradient [L/L] (0.02 to 0.006 ft/ft)

n_e = Effective porosity (0.25).

Using this relationship in conjunction with site-specific data, the average advective groundwater velocity south of the Upper Naknek Site is in the range of 0.002 ft/min to 0.0006 ft/min (1,051 to 315 ft/year). The median velocity is 0.0013 ft/min (683 ft/year).

3.3.2 Potential Pathways and Receptors

Pathways to potential receptors for contaminants in groundwater may include discharge of contaminated groundwater into downgradient wetland areas and to the ground surface, migration to the Naknek River, or migration of the contaminant plume into downgradient potable and nonpotable water wells.

Groundwater supply wells installed by the Air Force at KSA are all screened in the C-Aquifer (approximately 200 feet bgs) and are unlikely to be affected by contamination from SS-12. As noted before, previous studies have indicated that there are two aquitards separating the C-Aquifer from the surficial aquifer. Private wells off KSA property and in the town of King Salmon are generally screened in the B-Aquifer. However, no private or military potable water wells were observed at the Upper or Lower Naknek Site. A greater risk of groundwater contamination exists for the B-Aquifer from downward migration of contamination through the A-Aquitard barrier. Downward migration may not be a potential problem in all areas because the potentiometric surface of the B-Aquifer has been recorded as nearly equivalent to the A-Aquifer in many locations, which suggests a minimal or nonexistent vertical hydraulic gradient downward from the A-Aquifer to the B-Aquifer.

Groundwater at the Upper Naknek Site may ultimately discharge into the Naknek River, which is approximately 1,000 feet south of the current downgradient edge of the hydrocarbon plume. Potential surface water contamination also exists in the wetland area separating the Upper Naknek from the Lower Naknek Site. A french drain has been installed on the downgradient side of fuel contamination in an effort to limit further downgradient migration of contaminants.

SECTION 4

NATURE AND EXTENT OF CONTAMINATION AND SOIL AND GROUNDWATER GEOCHEMISTRY

4.1 SOURCE OF CONTAMINATION

The Upper Naknek Site contained numerous USTs and ASTs used mostly for jet fuel (JP-4) and diesel fuel. All ASTs have been removed from the Upper Naknek Site. The exact number of operative and inoperative USTs still buried at the site is unknown. As a result, the sources of fuel releases contributing to groundwater contamination are ambiguous. Most operating USTs appear to be within the fenced area in the northeastern part of the site, upgradient of contamination seen in the eastern part of the site. JP-4 contamination in this area may have been released from underground pipelines or leaking USTs. The sources of site contamination in the western portion of the site likely were former USTs; this area is now occupied by barrel shredding and land farming operations.

4.2 SOIL CHEMISTRY

4.2.1 Mobile LNAPL Contamination

Mobile LNAPL is defined as LNAPL that is free to flow in the aquifer and that will flow from the aquifer matrix into a well under the influence of gravity. On the basis of reports of visible hydrocarbon sheens on wetland waters, LNAPL from the Upper Naknek Site was believed to be entering the wetlands immediately to the south of the site in 1992. SAIC (1993c) was contracted to install a french drain and lateral trench for product recovery. To date, insufficient product has been collected at the site for accurate analysis. Below the french drain, surface water sheens resembling hydrocarbon contamination were observed in the wetland during the Parsons ES field study in September 1994.

The presence of LNAPL in monitoring wells was never recorded in previous IRP studies. However, LNAPL contamination was detected in monitoring well 500 (<1 cm) during September 1994 sampling. LNAPL was not documented at any of the adjacent wells (ESMW-15A, MW-51, or ESMW-9A). Therefore, the maximum areal extent of mobile LNAPL contamination is an area 300-feet (east/west) by 100-feet (north/south). The relationship between measured LNAPL thickness and the amount of mobile LNAPL in the subsurface at a site is difficult to quantify. It is well documented that LNAPL thickness measurements taken in groundwater monitoring wells are not indicative of actual mobile LNAPL thickness in the formation (Kemblowski and Chiang, 1990; Abdul *et al.*, 1989; Testa and Paczkowski, 1989; Hughes *et al.*, 1988; Blake and Hall, 1984; Hall *et al.*, 1984; Mercer and Cohen, 1990; de Pastrovich *et al.*, 1979; Lehnard and Parker, 1990; Ballesterio *et al.*, 1994). It has been noted by these authors that the thickness of LNAPL measured in a monitoring well is greater than the actual mobile LNAPL thickness present in the

aquifer and, according to Mercer and Cohen (1990), measured LNAPL thickness in wells is typically 2 to 10 times greater than the actual mobile LNAPL thickness in the formation. Considering that only 0.2 inches of LNAPL was detected at the site in a single well, it does not appear that significant volumes of mobile LNAPL are present at the site.

4.2.2 Residual LNAPL Contamination

Residual LNAPL is defined as the LNAPL that is trapped in the aquifer by the processes of cohesion and capillarity, and therefore will not flow within the aquifer and will not flow from the aquifer matrix into a well under the influence of gravity. Results of previous soil sampling efforts (CH₂M Hill, 1990; SAIC, 1992; EMCON, 1994a) were coupled with recent September 1994 investigative results in the sections below to describe the extent of soil contamination.

4.2.2.1 Soil BTEX Contamination

BTEX compounds were detected at low concentrations in soil boreholes ESMW-8B and ESMW-10B during September 1994. The highest total BTEX concentration detected at that time was 1.6 milligrams per kilogram (mg/kg) at ESMW-10B (0 to 2 feet bgs). The relative absence of significant BTEX concentrations in the soil corroborates soil results obtained by EMCON (1994a) in 1993. During the 1993 sampling, a sample from soil boring 503 contained 51 micrograms per kilogram (µg/kg) of ethylbenzene and 190 µg/kg of total xylenes. All other VOCs detected in the soil and sediment samples taken by EMCON were suspected to be laboratory contaminants, including methylene chloride and acetone. Soil sampling conducted by CH₂M Hill (1990) detected no significant concentrations of BTEX at the site. The low soil BTEX concentrations consistently measured at the site suggests that petroleum hydrocarbon contamination, where detected, is weathered [elevated levels of total recoverable petroleum hydrocarbons (TRPH) (Section 4.2.2.2) were detected in the areas of low BTEX contamination].

4.2.2.2 Soil TRPH and DRO Contamination

TRPH contamination in the soil was first quantified in 1990 by CH₂M Hill. Elevated TRPH concentrations were encountered near MW-50, MW-88, and MW-52. These TRPH detections suggest the presence of more than one contaminant source at the site. The easternmost TRPH detection (MW-52) may be associated with the pipeline corridor. TRPH was most extensively delineated in 1993 by EMCON (1994a). TRPH was detected in soil borings 499, 500, 501, 502, 507, 509, and 510. The highest concentration was 9,200 mg/kg, at a depth of 10 feet bgs in soil boring 499. Concentrations in the rest of the samples were below 2,000 mg/kg (EMCON, 1994a). Fifteen of 18 soil samples contained diesel-range organic (DRO) contamination, with concentrations exceeding 100 mg/kg at borings 499 (7,100 mg/kg at 10 feet bgs) and 502 (850 mg/kg at the surface). Boring 499 was located near the former bulk fuel storage area and indicates petroleum hydrocarbon contamination near the groundwater surface. Soil boring 502 is located along the former aboveground pipeline and indicates surficial soil contamination.

TRPH data collected by Parsons ES in September 1994 were limited to analysis of samples from soil borings ESMW-8 and ESMW-10. TRPH concentrations were quantified as total fuel carbon in comparison to a JP-4 fuel standard, using Method RSKSOP-72, revision 1. Soil TRPH concentrations were 36 mg/kg for both soil boring ESMW-8 (12-14 ft bgs) and soil boring ESMW-10 (0-2 ft bgs), slightly above the laboratory's quantification limit of 15.0 mg/kg. Figure

4.1 illustrates the extent of soil gas TPH, soil DRO, and soil BTEX concentrations at the Upper Naknek Site using current (1994) and older data (1993). Table 4.1 lists soil analytical data from the September 1994 site characterization.

4.2.3 Total Organic Carbon

TOC concentrations are used to estimate the amount of organic matter sorbed on soil particles or trapped in the interstitial passages of a soil matrix. The TOC concentration in the saturated zone is an important parameter used to estimate the amount of contaminant that could potentially be sorbed to the aquifer matrix. Sorption results in retardation of the contaminant plume relative to the average advective groundwater velocity. Measurements of soil TOC were made at soil boring locations ESMW-8, ESMW-10, and ESMW-13. The TOC content of the soil from these borings ranged from 0.021 to 1.90 percent (Table 4.2).

The highest TOC content in soils (1.90 percent) was measured at ESMW-13 which is downgradient of the contaminant plume. TOC concentrations at ESMW-8 and ESMW-10, within areas of soil contamination, ranged from 0.021 to 1.32 percent. The high TOC content at ESMW-13, relative to ESMW-8 and ESMW-9, may be a result of organic debris from the arctic forest in the area.

4.3 GROUNDWATER CHEMISTRY

Three lines of evidence can be used to document the occurrence of natural attenuation: 1) documented loss of contaminant mass at the field scale; 2) geochemical evidence; and 3) laboratory microcosm studies. The second line of evidence (geochemical evidence) is used herein to support the occurrence of natural attenuation, as described in the following sections. Because this line of evidence strongly suggests that natural attenuation is occurring at this site, laboratory microcosm studies were not deemed necessary.

4.3.1 Dissolved Contamination

Laboratory analytical results for groundwater samples collected during previous site investigations indicated the presence of fuel hydrocarbon contamination in the shallow saturated zone at the Upper Naknek Site. Groundwater samples collected in September 1994, by Parsons ES and RSKERL personnel confirmed these results. Table 4.3 summarizes groundwater contaminant data for these samples.

4.3.1.1 BTEX in Groundwater

Figure 4.2 is an isopleth map showing the distribution of total BTEX dissolved in groundwater in September 1994. Where nested wells are present, isopleths are drawn based on the maximum concentration detected at each location. Dissolved BTEX contamination emanating from the former USTs near the shredded drum pile is migrating south and southeast in the direction of groundwater flow. An eastern plume, originating in the fenced fuel area, is also migrating to the south, eventually connecting with the western plume. At downgradient locations, it is impossible to distinguish between the eastern and western plumes. As indicated by the 1 microgram per liter ($\mu\text{g/L}$) isopleth, the entire plume at the Upper Naknek Site is approximately 850 feet long by 900 feet wide. The downgradient extent of BTEX contamination underlies the wetland area directly south of the Upper Naknek Site. Beneath the wetland,

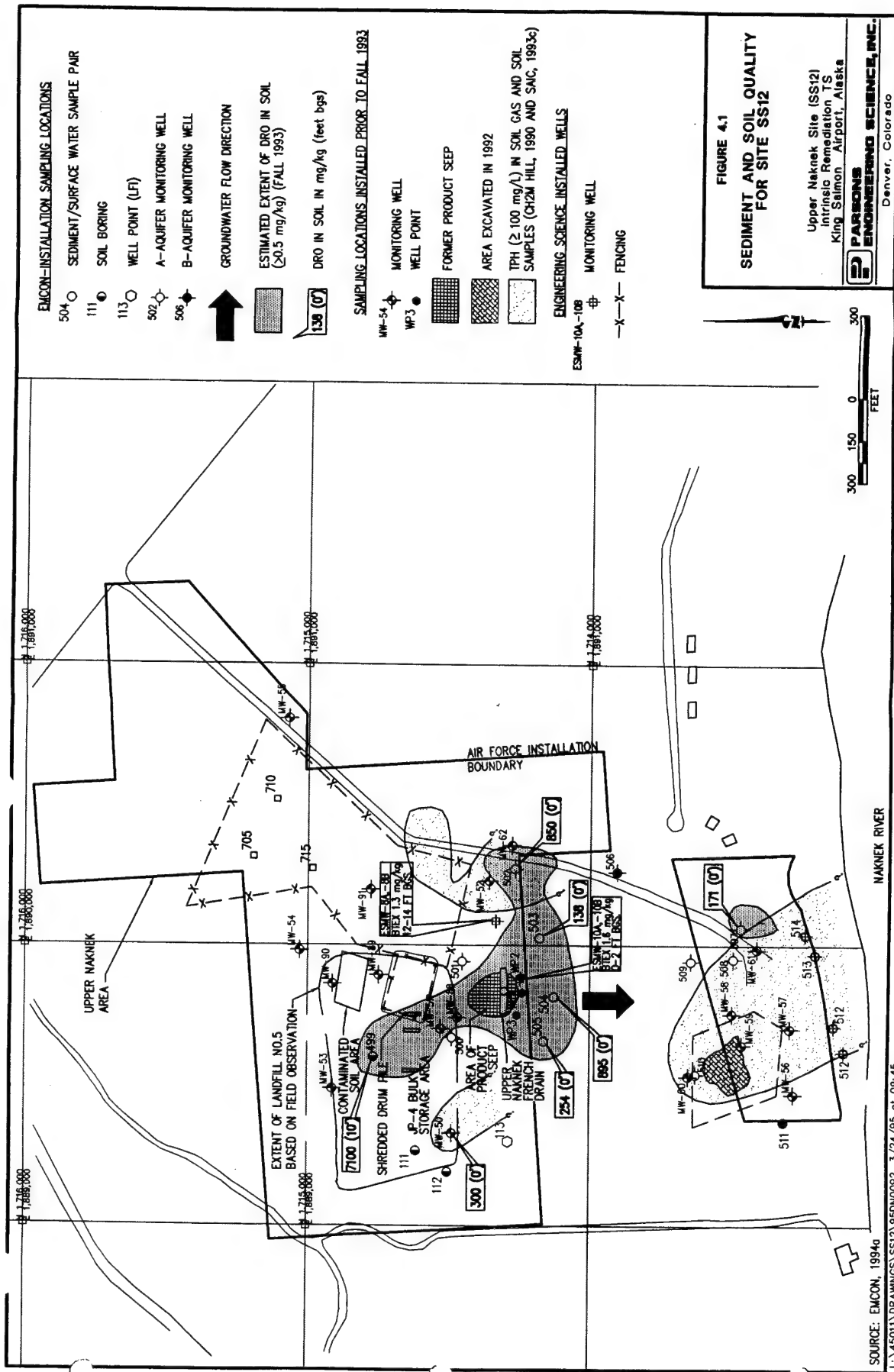


TABLE 4.1
PETROLEUM HYDROCARBON COMPOUNDS DETECTED IN SOIL
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

Sample Location	Sample Date	Sample Depth (feet)	JP-4 ^a (mg/kg)	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	p-xylene (mg/kg)	m-Xylene (mg/kg)	o-Xylene (mg/kg)	Total Xylenes (mg/kg)	Total BTEX (mg/kg)	1,3,5-TMB (mg/kg)	1,2,4-TMB (mg/kg)	1,2,3-TMB (mg/kg)
ESMW8	9/20/1994	16-18	11.0	6.73	57.3	11.3	12.6	18.2	20.3	51.1	126	24.5	45.1	18.9
ESMW8B	9/20/1994	12-14	36.0	73.6	675	105	92.9	171	184	448	1,300	94.9	204	136
ESMW10	9/21/1994	0-2	36.6	44.5	13.8	201	345	466	526	1,340	1,600	526	929	588
ESMW10	9/21/1994	3-5	7.85	24.6	15.3	61.9	98.2	117	115	330	432	109	201	119
ESMW10	9/21/1994	13-15	3.12	<20	<20	6.51	1.06	<20	<20	1.06	7.57	<20	6.40	ND ^c
UNSS-3	7/27/1995	Sediment	NA	ND	BLQ ^b	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	58.8	43.1
UNSS-4	7/27/1995	Sediment	NA	BLQ	BLQ	84.8	319	121	134	574	659	234	233	173
UNSS-5	7/27/1995	Sediment	NA	BLQ	BLQ	BLQ	53.8	45.8	63.0	163	163	39.6	51.8	42.1
UNSS-6	7/27/1995	Sediment	NA	ND	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	59.3	BLQ

^a JP-4 = Total fuel carbon quantified against a JP-4 fuel standard.

^b NA = Not analyzed for

^c ND = Not detected

^d BLQ = Below limit of quantitation, 0.05 mg/mL

Note: Total fuel carbon (JP-4 standard) analyzed with RSKSOP-72.
 BTEX and TMB compounds analyzed with RSKSOP-124.

TABLE 4.2
TOTAL ORGANIC CARBON IN SOIL
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

Sample Location	Sample Date	Sample Depth (feet bgs)	Soil Filtrate %TOC	Solids %TOC	Total Soil %TOC	Mean Soil %TOC
ES-MW8B	9/94	12 - 14	0.033	0.102	0.132	
ES-MW8B(D) ^{a/}	9/94	12 - 14	0.030	0.102	0.132	0.132
ES-MW8B	9/94	16 - 18	<0.001	0.026	0.026	
ES-MW8B(D)	9/94	16 - 18	0.002	0.019	0.021	0.024
ES-MW10A	9/94	0 - 2	0.102	1.22	1.32	
ES-MW10A(D)	9/94	0 - 2	0.102	1.20	1.30	1.31
ES-MW10A	9/94	3 - 5	0.066	0.720	0.786	
ES-MW10A(D)	9/94	3 - 5	0.067	0.664	0.731	0.759
ES-MW10A	9/94	13 - 15	0.147	0.923	1.07	
ES-MW10A(D)	9/94	13 - 15	0.147	0.889	1.04	1.05
ES-MW13B	9/94	4 - 5	0.349	1.50	1.85	
ES-MW13B(D)	9/94	4 - 5	0.356	1.55	1.90	1.88

^{a/} (D) = Duplicate sample.

Note: TOC was analyzed using RSKSOP-102.

TABLE 4.3
PETROLEUM HYDROCARBON COMPOUNDS DETECTED IN GROUNDWATER
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

Sample Location	Sample Date	Northing	Easting	Diesel Fuel ^u (mg/L)	TPH ^u (mg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	1,3,5-TMB (µg/L)	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	Fuel Carbon (µg/L)
ES-MW08A	9/22/94	1714720.83	750058.14	NA ^v	NA	274	2,970	375	291	690	661	1,640	5,260	124	352	334	7,710
ES-MW08B	9/22/94	1714717.78	750058.45	NA	NA	ND ^u	1.41	<1	ND	<1	1.27	2.68	<1	ND	ND	3.05	36.1
ES-MW09A	9/22/94	1714648.98	749690.77	NA	NA	5.90	ND	10.7	7.80	7.57	5.08	20.5	37.1	1.16	1.03	ND	4.92
ES-MW10A	9/22/94	1714630.73	749833.07	NA	NA	14.0	0.97	20.7	32.6	34.7	33.3	101	136	16.1	39.1	36.5	496
ES-MW10B	9/22/94	1714630.55	749832.60	NA	NA	ND	ND	ND	<1	<1	<1	<1	<1	1.06	1.53	1.83	15.2
ES-MW12A	9/20/94	1714372.28	750075.50	NA	NA	4.96	<1	ND	<1	ND	ND	<1	4.96	ND	ND	ND	7.70
ES-MW13A	9/23/94	1714239.65	750048.82	NA	NA	3.12	ND	1.34	1.59	<1	ND	1.59	6.05	ND	ND	ND	12.2
ES-MW14A	9/23/94	1714034.10	749874.14	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ES-MW15A	9/22/94	1714763.18	749487.24	NA	NA	ND	ND	2.50	2.96	ND	ND	2.96	5.46	ND	ND	1.18	92.70
ES-MW15B	9/22/94	1714763.46	749497.86	NA	NA	<1	5.57	17.2	32.9	6.50	2.10	41.5	64.3	25.6	1.25	15.7	499
MW50	8/14/89	1714786.19	749323.67	16.0	NA	6.23	NA	NA	NA	NA	NA	NA	6.23	NA	NA	NA	NA
MW50	9/17/94	1714786.19	749323.67	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW51	8/14/89	1714770.25	749488.43	2.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW51	9/16/94	1714770.25	749488.43	NA	NA	3.43	205	108	131	274	147	552	888	73.8	101	62.4	1,560
MW52	8/13/89	1714656.18	750223.58	3.8	NA	20.2	NA	NA	NA	NA	NA	NA	20.2	NA	NA	NA	NA
MW52	9/17/94	1714656.18	750223.58	NA	NA	23.1	9.43	28.3	20.0	3.74	1.70	25.44	86.3	3.41	ND	3.62	250
MW53	7/30/89	1715210.10	749482.68	ND	NA	0.01	ND	ND	ND	ND	ND	ND	0.01	NA	NA	NA	NA
MW53	9/17/94	1715210.10	749482.68	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW54	8/12/89	1715177.25	750080.79	ND	NA	0.40	NA	NA	NA	NA	NA	NA	0.40	NA	NA	NA	NA
MW55	8/2/89	1715248.19	750946.95	ND	NA	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW56	8/17/89	NA	NA	ND	NA	0.07	NA	NA	NA	NA	NA	NA	0.07	NA	NA	NA	NA
MW57	8/6/89	1713498.45	749844.43	ND	NA	3.40	NA	NA	NA	NA	NA	NA	3.40	NA	NA	NA	NA
MW58	8/16/89	1713694.49	749889.21	3.0	NA	2.14	NA	NA	NA	NA	NA	NA	2.14	NA	NA	NA	NA
MW60	9/17/94	1713829.21	749657.07	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW61	8/8/89	1713624.14	750104.32	ND	NA	0.89	NA	NA	NA	NA	NA	NA	0.89	NA	NA	NA	NA
MW88	9/3/92	1714766.78	749842.40	ND	NA	0.65	NA	NA	NA	NA	NA	NA	0.65	NA	NA	NA	NA
MW88	9/16/94	1714766.78	749842.40	NA	NA	ND	ND	<1	2.62	<1	ND	2.62	2.62	6.17	3.62	14.5	243
MW89	9/4/92	1715046.90	749888.56	ND	NA	2.37	NA	NA	NA	NA	NA	NA	2.37	NA	NA	NA	NA
MW89	9/16/94	1715046.90	749888.56	NA	NA	ND	ND	<1	ND	ND	ND	ND	<1	ND	ND	ND	<1
MW90	9/7/92	1715209.67	749856.27	ND	NA	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW90	9/16/94	1715209.67	749856.27	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

TABLE 4.3 (Concluded)
PETROLEUM HYDROCARBON COMPOUNDS DETECTED IN GROUNDWATER
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

Sample Location	Sample Date	Northing	Easting	Diesel Fuel ^a (mg/L)	TPH ^a (mg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	1,3,5-TMB (µg/L)	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	Fuel Carbon (µg/L)
MW91	9/28/92	1715077.52	750191.76	ND	NA	0.06	NA	NA	NA	NA	NA	NA	0.06	NA	NA	NA	NA
MW91	9/20/94	1715077.52	750191.76	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
WP1	9/19/94	1714563.35	749846.02	NA	NA	<1	<1	ND	<1	<1	<1	<1	<1	1.18	1.20	1.32	6.66
WP2	9/19/94	1714555.41	749902.48	NA	NA	1.04	1.82	ND	0.96	ND	ND	0.96	3.82	ND	ND	ND	5.87
WP3	9/19/94	1714576.23	749753.70	NA	NA	1.69	25.9	ND	ND	ND	ND	ND	28	ND	ND	ND	24.7
500	10/25/93	1714756.56	749686.11	ND	39.0	2.70	3.10	36.0	NA	NA	NA	NA	42	100	9.00	ND	NA
500	9/16/94	1714756.56	749686.11	NA	NA	4.36	8.07	64.6	105	127	107	339	416	109	218	160	2,180
501	10/25/93	1714750.77	749937.57	ND	ND	1.60	3.50	28.0	NA	NA	NA	180	213	100	ND	ND	NA
501	9/16/94	1714750.77	749937.57	NA	NA	ND	ND	ND	<1	ND	ND	<1	<1	ND	ND	ND	<1
502	10/25/93	NA	NA	ND	ND	210	11.0	370	NA	NA	NA	2,300	2,890	28.0	20.0	ND	NA
506	11/9/93	1714205.22	750254.74	0.1	ND	ND	3.00	ND	NA	NA	NA	ND	3.00	ND	ND	ND	NA
506	9/22/94	1714205.22	750254.74	NA	NA	ND	6.60	ND	ND	ND	ND	ND	6.60	ND	ND	ND	77.7
507	10/24/93	1713765.31	750054.77	ND	ND	ND	ND	ND	NA	NA	NA	2.00	2.00	ND	ND	ND	NA
507	9/22/94	1713765.31	750054.77	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
508	10/24/93	1713791.01	749945.45	ND	ND	ND	0.60	ND	NA	NA	NA	ND	0.60	ND	ND	ND	NA
508	9/20/94	1713791.01	749945.45	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
509	10/24/93	1713899.66	749898.95	ND	ND	ND	ND	ND	NA	NA	NA	ND	ND	ND	ND	ND	NA
509	9/17/94	1713899.66	749898.95	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
510	10/24/93	NA	NA	ND	ND	ND	ND	ND	NA	NA	NA	ND	ND	ND	ND	ND	NA

^a Diesel fuel quantified using Method M8100.

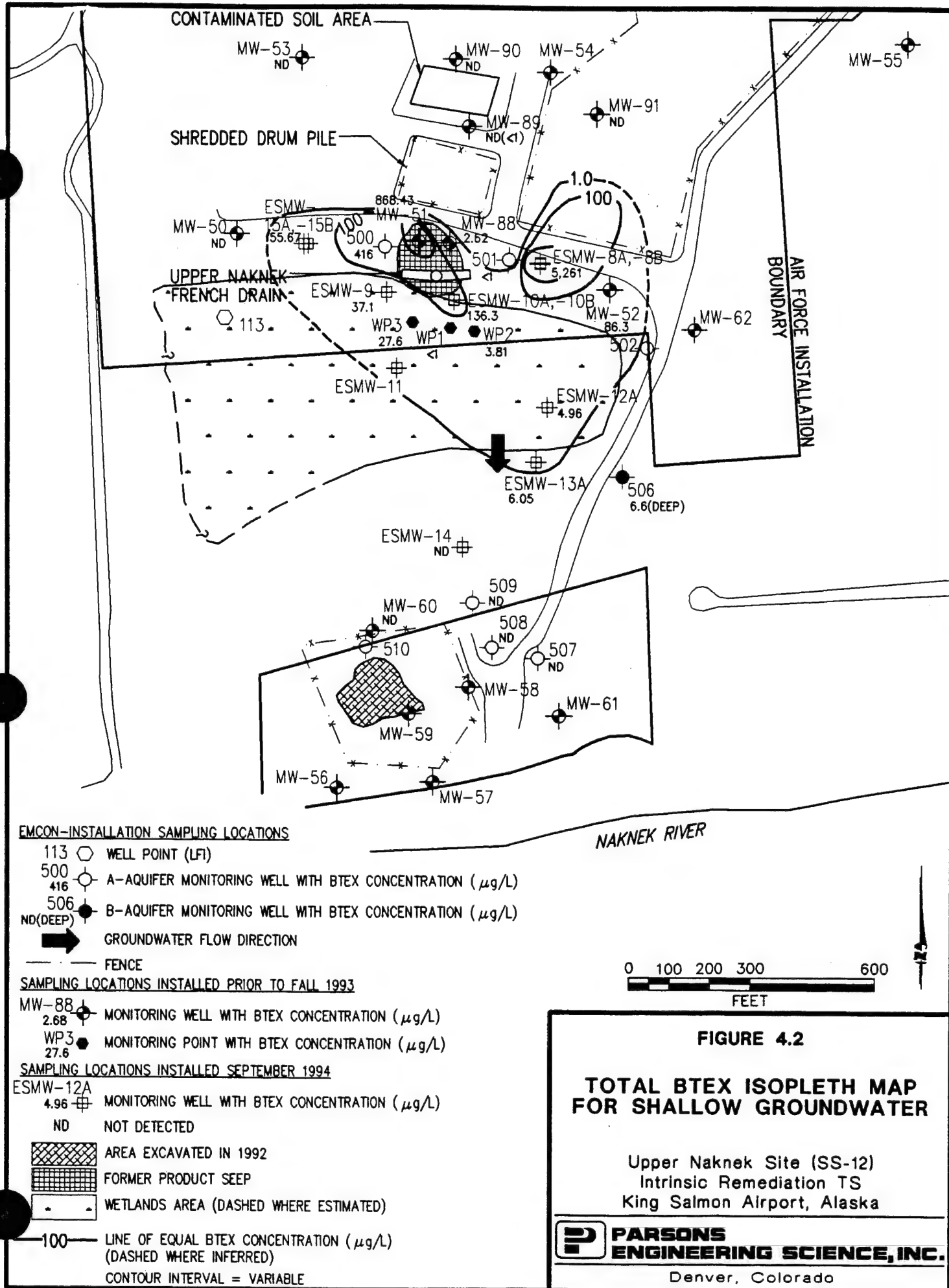
^b TPH quantified using Method E418.1.

^c NA=Not Available.

^d ND=Not detected.

Note: BTEX, TMB, and Fuel Carbon analyses performed in 1994 using RSKSOP-133.

BTEX analyses performed in 1989, 1992, and 1993 using SW8260.



benzene equals or exceeds the Federal MCL of 5 µg/L at ESMW-9 and ESMW-10 with concentrations of 5.9 µg/L and 14.0 µg/L, respectively. The other BTEX constituents (toluene, ethylbenzene, and xylene) are below federal MCLs in groundwater beneath the wetland. Specific concerns regarding contaminant migration from the groundwater to surface waters or soils of the wetland are discussed in Section 6.

Three nested wells were installed at the Upper Naknek site. Monitoring well locations ESMW-8 and ESMW-10 exhibited higher BTEX concentrations across the water table (5,260 µg/L and 136 µg/L, respectively) with lower concentrations deeper in the aquifer (2.68 µg/L and <1 µg/L, respectively). Monitoring well location ESMW-15 exhibited a lower BTEX concentration at depth (55.7 µg/L) with a lower concentration across the water table (5.5 µg/L). The occurrence of BTEX contamination at depth suggests the potential that BTEX contamination may extend through the full saturated aquifer thickness. At one well screened in the B-Aquifer (monitoring well 506), toluene was detected at low concentrations (<7 µg/L) during two separate sampling events (Table 4.2). These concentrations of toluene suggest that contaminants may have migrated through the A-Aquitard and reached the lower aquifer. However, other possible explanations for B-Aquifer contamination include cross-contamination induced during drilling, leakage through the annular seal of the monitoring well, cross-contamination of the sampling equipment, or laboratory contamination. In any event, BTEX concentrations in the B-Aquifer do not exceed state or federal regulatory standards.

Where detected, total BTEX concentrations ranged from <1 to 5,260 µg/L. As indicated on Figure 4.2, the highest BTEX concentrations detected in the western and eastern plumes were 868 µg/L (MW-51) and 5,260 µg/L (ESMW-8A), respectively. Benzene concentrations, where detected, ranged from 1.04 to 274 µg/L. At four locations (ESMW-8A, ESMW-9A, ESMW-10A, and MW-52), the benzene concentration exceeded the federal maximum contaminant level (MCL) of 5 µg/L. Toluene concentrations ranged from 0.965 to 2,970 µg/L, but the federal MCL of 1,000 µg/L was exceeded only at ESMW-8A (2,970 µg/L). Ethylbenzene concentrations ranged from 1.34 to 375 µg/L, which are all below the federal MCL of 700 µg/L. Total xylene concentrations ranged from 0.96 to 1,640 µg/L, and were also all below the federal MCL of 10,000 µg/L.

Groundwater analytical results obtained prior to the September 1994 (Parsons ES) investigation showed similar concentration ranges for BTEX compounds, especially benzene. During a groundwater characterization study performed by SAIC (1992), 2 years prior to the Parsons ES field effort, benzene contamination was detected at several wells. Groundwater from MW-51 contained benzene (48 µg/L), toluene (640 µg/L), and total xylenes (576 µg/L), all at higher concentrations than detected in September 1994. Benzene was above the federal MCL of 5 µg/L in wells MW-51, MW-52, and WP-2. In contrast, groundwater samples collected in 1993 by EMCON (1994a) at monitoring well 500 had benzene concentrations in the low microgram-per-liter range that were in the same range (<5 µg/L) as benzene concentrations detected in September 1994. Site data do not support a uniform decrease of benzene at the site between 1993 and 1994.

The observed extent of BTEX contamination for the western and eastern plumes suggests that natural attenuation is limiting plume migration. Given that releases of petroleum hydrocarbons have occurred at least since the mid 1980s (and probably earlier), and given the median advective groundwater velocity calculated in Section 3.3.3.4 (683 ft/yr), it is reasonable to expect that the plume would be much longer than was observed in 1994, possibly reaching the Naknek River.

Instead, the leading edge of the Upper Naknek groundwater BTEX plumes appears to be in the vicinity of the wetland area, nearly 1,000 feet upgradient from the bank of the Naknek River.

4.3.1.2 Total Fuel Carbon in Groundwater

Figure 4.3 is an isopleth map showing the distribution of total fuel carbon (analyzed using RSKSOP-133) dissolved in groundwater in June 1994. The dissolved fuel carbon contamination pattern is very similar to the BTEX plume configuration shown on Figure 4.1. Where detected, total fuel carbon concentrations range from 1.22 to 7,710 µg/L.

4.3.2 Inorganic Chemistry and Geochemical Indicators of Biodegradation

Microorganisms obtain energy for cell production and maintenance by facilitating the transfer of electrons from electron donors to electron acceptors. This results in the oxidation of the electron donor and the reduction of the electron acceptor. Electron donors at the Upper Naknek Site are natural organic carbon and fuel hydrocarbon compounds. Fuel hydrocarbons are completely degraded or detoxified if they are utilized as the primary electron donor for microbial metabolism (Bouwer, 1992). Electron acceptors are elements or compounds that occur in relatively oxidized states, and include oxygen, nitrate, ferric iron, sulfate, and carbon dioxide. Microorganisms preferentially utilize electron acceptors while metabolizing fuel hydrocarbons (Bouwer, 1992). Under aerobic conditions, DO is utilized first as the prime electron acceptor. After the DO is consumed, anaerobic microorganisms use electron acceptors in the following order of preference: nitrate, ferric iron hydroxide, sulfate, and finally carbon dioxide.

Depending on the types and concentrations of electron acceptors, pH conditions, and redox potential, anaerobic biodegradation can occur by denitrification, ferric iron reduction, sulfate reduction, or methanogenesis. Other, less common anaerobic degradation mechanisms such as manganese reduction may dominate if the physical and chemical conditions in the subsurface favor use of these electron acceptors. Anaerobic destruction of the BTEX compounds is associated with the accumulation of fatty acids, production of methane, solubilization of iron, and reduction of nitrate and sulfate (Cozzarelli *et al.*, 1990; Wilson *et al.*, 1990). Environmental conditions and microbial competition will ultimately determine which processes will dominate. Vroblesky and Chapelle (1994) show that the dominant terminal electron accepting process can vary both temporally and spatially in an aquifer with fuel hydrocarbon contamination.

DO data for the Upper Naknek Site suggest that aerobic biodegradation of hydrocarbons is occurring. In addition, data for ferrous iron and methane in groundwater at the Upper Naknek Site suggest that anaerobic degradation via ferric iron reduction and methanogenesis is occurring at various locations in limited amounts. Further indication of intrinsic remediation is provided by results of volatile fatty acids analyses performed on select groundwater samples. Geochemical parameters for groundwater at the Upper Naknek Site are discussed in the following sections.

4.3.2.1 Dissolved Oxygen

DO concentrations were measured at monitoring wells in September 1994. Table 4.4 summarizes DO concentrations, and Figure 4.4 is an isopleth map showing the distribution of DO concentrations in groundwater. Comparison of Figures 4.2 and 4.4 shows graphically that areas with elevated total BTEX concentrations correlate with areas with depleted DO

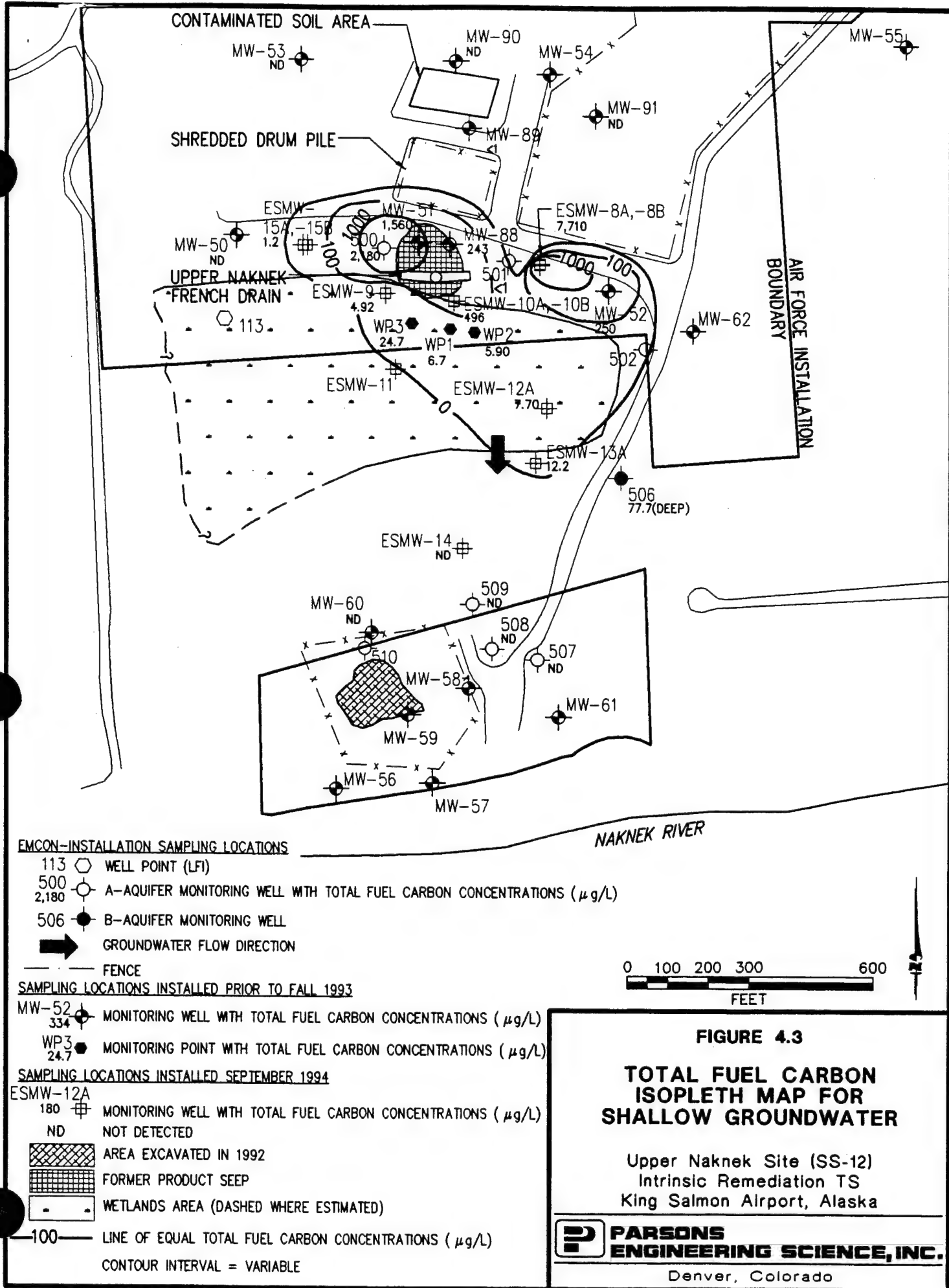


TABLE 4.4
GEOCHEMICAL DATA FOR GROUNDWATER
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

Sample Location	Northing	Easting	TOC (mg/L)	Temperature (°C)	Dissolved Oxygen (mg/L)	pH (Std. Units)	Redox Potential (mV)	Chloride (mg/L)	Sulfate (mg/L)	Ferrous Iron (mg/L)	Soluble Manganese (mg/L)	Free CO ₂ (mg/L)	NO ₂ + NO ₃ Nitrogen (mg/L)	Methane (mg/L)	Conductivity (µs/cm)	Alkalinity as CaCO ₃ (mg/L)
ESMW-8A	1714720.83	750058.14	70.0	8.0	0.3	6.5	-17	4.33	<0.5	32.0	0.8	280	0.06	3.582	432	256
ESMW-8B	1714717.78	750058.45	4.0	6.7	0.7	7.4	27	2.57	1.36	<0.05	<0.1	38	0.06	0.133	182	80
ESMW-10A	1714630.73	749853.07	10.4	6.9	0.8	6.3	253	4.57	8.54	<0.05	<0.1	46	0.30	1.501	204	98
ESMW-10B	1714630.55	749852.60	2.6	5.8	6.7	7.2	255	3.61	2.45	<0.05	<0.1	12	0.10	0.010	110	49
ESMW-12A	1714372.28	750075.50	35.5	8.0	0.8	6.1	180	3.77	<0.5	7.2	<0.1	106	NA ^a	3.004	63	86
ESMW-13A	1714239.45	750048.51	12.4	4.0	0.1	6.5	-15	4.16	0.66	20.0	<0.1	176	0.09	4.234	155	119
ESMW-14A	1714034.10	749874.14	2.2	4.5	0.7	6.5	110	3.67	3.81	0.2	<0.1	94	0.11	0.033	80	34
ESMW-15A	1714763.18	749487.24	24.9	7.5	1.8	6.2	NA	5.21	5.38	40.0	0.5	>300	0.14	7.636	251	153
ESMW-15B	1714763.46	749497.86	5.6	7.5	0.2	7.0	30	2.20	1.56	0.2	0.3	42	0.11	0.005	212	136
500	1714756.56	749686.11	17.7	5.8	0.2	6.4	-25	4.08	1.57	30.0	0.3	165	0.05	NA	274	172
501	1714750.77	749937.57	7.6	5.2	3.6	5.7	186	3.74	4.18	<0.05	<0.1	40	0.07	0.004	112	18
506	1714205.22	750254.74	0.7	6.5	0.3	7.7	-260	4.05	12.30	<0.05	<0.1	8	NA	NA	122	34
507	1713765.31	750054.77	1.6	7.8	1.6	6.4	195	4.37	3.56	0.2	<0.1	48	0.09	0.011	64	68
508	1713791.01	749945.45	1.4	6.5	4.4	6.1	215	3.49	2.06	0.1	<0.1	36	<0.05	NA	45	48
509	1713899.66	749898.95	1.5	7.2	4.8	5.7	183	NA	NA	<0.05	<0.1	32	0.07	NA	NA	12
MW-50	1714754.19	749934.17	1.3	7.8	10.5	6.3	214	1.94	<0.5	<0.05	<0.1	16	NA	NA	48	14
MW-51	1714770.25	749488.43	12.6	7.0	0.1	6.6	-50	3.28	1.09	11.4	0.7	100	<0.05	0.162	368	205
MW-52	1714656.18	750223.58	16.4	8.3	0.5	6.4	-35	3.08	<0.5	5.9	0.3	60	<0.05	NA	187	93
MW-53	1715210.10	749482.68	1.1	7.2	10.9	6.3	195	6.12	<0.5	<0.05	<0.1	14	0.09	NA	108	38
MW-60	1713829.21	749657.07	3.1	7.1	4.3	5.8	200	3.84	<0.5	<0.05	0.1	40	0.09	NA	53	15
MW-88	1714766.78	749842.40	3.9	5.2	1.2	6.2	92	7.57	4.88	3.2	0.5	112	<0.05	NA	200	80
MW-89	1715046.90	749888.56	2.3	6.9	0.3	6.2	143	3.44	2.86	0.1	<0.1	24	0.05	NA	111	43
MW-90	1715209.67	749856.27	4.0	5.8	11.7	6.7	144	3.72	2.61	<0.05	<0.1	14	0.07	NA	90	33
MW-91	1715077.52	750191.76	0.7	6.8	0.2	7.3	220	2.92	3.33	<0.05	0.1	8	0.13	<0.001	86	35
WP-1	1714563.35	749846.02	7.9	8.7	1.0	6.4	37	15.20	<0.5	8.0	0.1	80	<0.05	0.768	174	96
WP-2	1714555.41	749902.48	12.7	9.8	2.5	6.9	-50	20.70	2.01	15.0	0.2	60	<0.05	1.351	245	140
WP-3	1714576.23	749753.70	NA	7.7	0.3	6.0	60	16.50	1.66	44.0	<0.1	200	0.13	5.612	85	69

^a NA = not available.

All data from September 1994 sampling.

Note: Analytical methods as follows:

TOC analyzed with RSKSOP-102.

Temperature, DO, pH, and Redox Potential analyzed with Orion meters 840 and 290A.

Chloride, Sulfate, NO₂ + NO₃, and Conductivity analyzed with EPA Methods 353.1, 120.1, and Waters capillary electrophoresis method N-601.

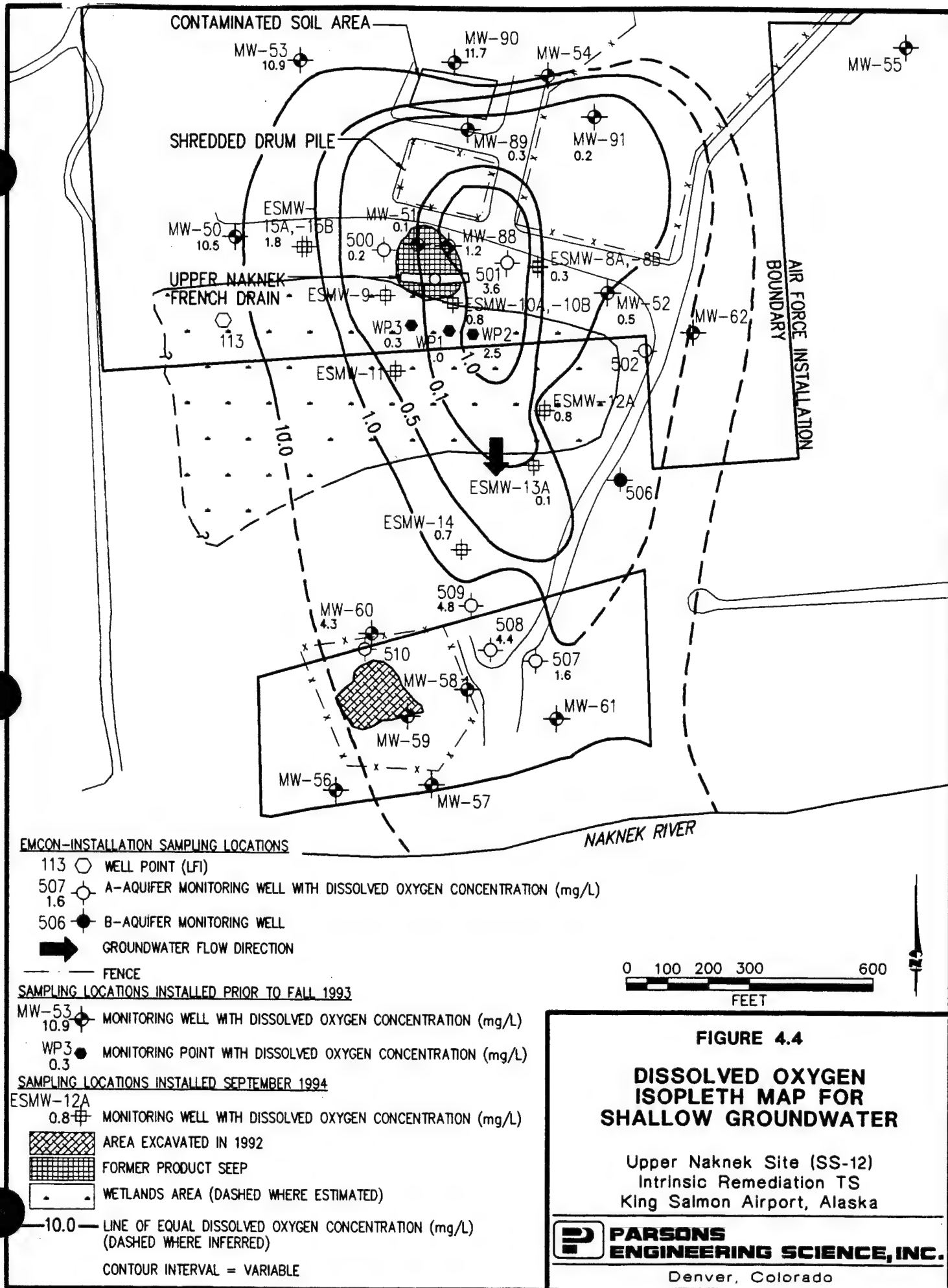
Ferrous iron analyzed with Hach Method 8146.

Soluble manganese analyzed with Hach Method 8034.

Free CO₂ analyzed with Hach Method 1436-01.

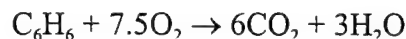
Methane analyzed with RSKSOP-147.

Alkalinity analyzed with Hach Method 8221.



concentrations. This is an indication that aerobic biodegradation of the BTEX compounds is occurring at the site. Based on the background DO levels measured at the site [up to 11.7 milligrams per liter (mg/L) outside of the BTEX plume], it appears that DO is an important electron acceptor at the Upper Naknek Site.

The following equations describe the overall stoichiometry of aromatic hydrocarbon mineralization caused by aerobic microbial biodegradation. In the absence of microbial cell production, the oxidation (mineralization) of benzene to carbon dioxide and water is given by:



Therefore, 7.5 moles of oxygen are required to metabolize 1 mole of benzene. On a mass basis, the ratio of oxygen to benzene is given by:

$$\text{Benzene} \quad 6(12) + 6(1) = 78 \text{ gm}$$

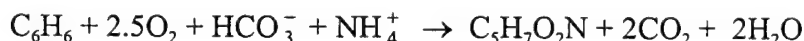
$$\text{Oxygen} \quad 7.5(32) = 240 \text{ gm}$$

$$\text{Mass Ratio of Oxygen to Benzene} = 240/78 = 3.08:1$$

Therefore, in the absence of microbial cell production, 3.08 mg of oxygen are required to completely metabolize 1 mg of benzene.

Similar calculations can be completed for toluene (3.13 mg oxygen to 1 mg toluene), ethylbenzene (3.17 mg oxygen to 1 mg ethylbenzene), and the xylenes (3.17 mg oxygen to 1 mg xylene). The average mass ratio of oxygen to total BTEX is thus 3.14:1. This means that approximately 0.32 mg of BTEX is mineralized for every 1.0 mg of DO consumed. With a background DO concentration of approximately 11.7 mg/L, the shallow groundwater at this site has the capacity to assimilate 3.73 mg/L (3,730 µg/L) of total BTEX through aerobic biodegradation. This is a conservative estimate of the assimilative capacity of DO because microbial cell mass production was not taken into account by the stoichiometry shown above.

When cell mass production is accounted for, the mineralization of benzene to carbon dioxide and water is given by:



From this it can be seen that only 2.5 moles of DO are required to mineralize 1 mole of benzene when cell mass production is taken into account. On a mass basis, the ratio of DO to benzene is given by:

$$\text{Benzene} \quad 6(12) + (6)1 = 78 \text{ gm}$$

$$\text{Oxygen} \quad 2.5(32) = 80 \text{ gm}$$

$$\text{Mass Ratio of Oxygen to Benzene} = 80/78 = 1.03:1$$

On the basis of these stoichiometric relationships, 1.03 mg of oxygen are required to mineralize 1 mg of benzene. Similar calculations can be made for toluene, ethylbenzene, and the xylenes. Based on these calculations, approximately 0.97 mg of BTEX is mineralized to carbon

dioxide and water for every 1.0 mg of DO consumed. With a background DO concentration of approximately 11.7 mg/L, the shallow groundwater at this site has the capacity to assimilate 11.35 mg/L (11,350 µg/L) of total BTEX if microbial cell mass production is taken into account.

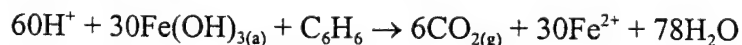
4.3.2.2 Nitrate/Nitrite

Concentrations of nitrate + nitrite (as N) were measured at groundwater monitoring points and existing monitoring wells in September 1994. Table 4.4 summarizes measured nitrate and nitrite concentrations. Nitrate concentrations are extremely low at this site, ranging from <0.05 mg/L to only 0.3 mg/L. Figure 4.5 is an isopleth map showing the distribution of nitrate + nitrite (as N) in groundwater. Comparison of Figure 4.2 with Figure 4.5 suggests that areas with elevated total BTEX concentrations exhibit slightly reduced nitrate + nitrite concentrations. However, the extremely low nitrate concentrations observed at this site suggest that anaerobic biodegradation of the BTEX compounds by nitrate reduction is not a significant removal mechanism.

4.3.2.3 Ferrous Iron

Ferrous iron (Fe^{2+}) concentrations were measured at groundwater monitoring wells in June 1994. Table 4.4 summarizes ferrous iron concentrations. Figure 4.6 is an isopleth map showing the distribution of ferrous iron in groundwater. Comparison of Figures 4.2 and 4.6 shows graphically that most of the area with elevated total BTEX concentrations have elevated ferrous iron concentrations. The highest measured ferrous iron concentration, 44 mg/L, was observed at monitoring well WP3, which is directly downgradient of areas of elevated BTEX concentration. Background levels of ferrous iron are generally at or below the detection limit of 0.05 mg/L, as measured at upgradient and downgradient wells with no detectable BTEX contamination. Elevated ferrous iron concentrations suggest that ferric iron hydroxide (Fe^{3+}) is being reduced to ferrous iron during biodegradation of BTEX compounds. Recent evidence suggests that the reduction of ferric iron to ferrous iron cannot proceed at all without microbial mediation (Lovley and Phillips, 1988; Lovley *et al.*, 1991; Chapelle, 1993). Hence, the elevated concentrations of ferrous iron measured in the contaminated groundwater at the Upper Naknek are indicators of microbial activity.

The following equations describe the overall stoichiometry of benzene oxidation by iron reduction caused by anaerobic microbial biodegradation. In the absence of microbial cell production, the mineralization of benzene is given by:

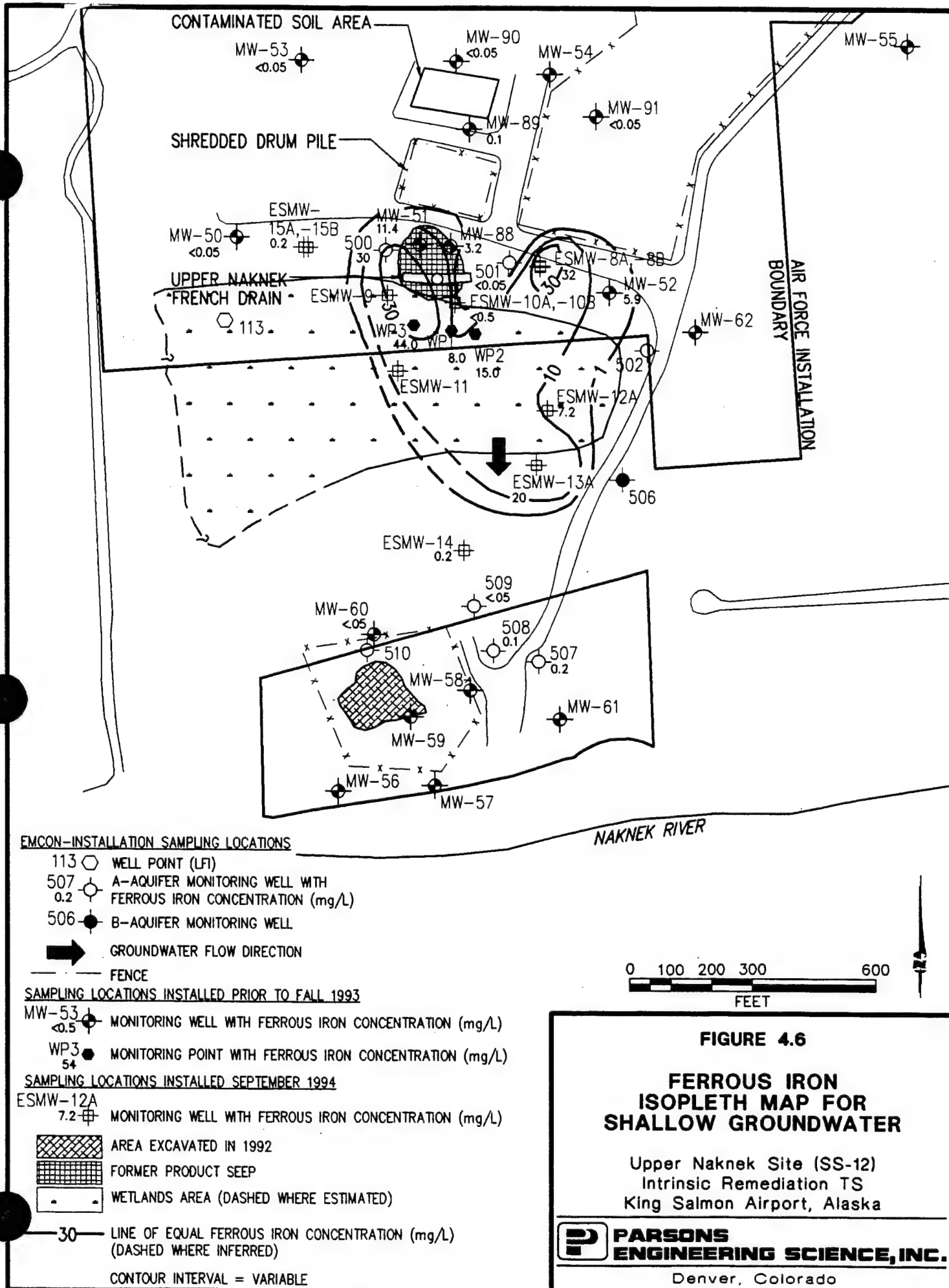


Therefore, 30 moles of ferric iron are required to metabolize 1 mole of benzene. On a mass basis, the ratio of ferric iron to benzene is given by:

$$\text{Benzene} \quad 6(12) + 6(1) = 78 \text{ gm}$$

$$\text{Ferric Iron} \quad 30(106.85) = 3205.41 \text{ gm}$$

$$\text{Mass ratio of ferric iron to benzene} = 3205.41/78 = 41.1:1$$



Therefore, in the absence of microbial cell production, 41.1 mg of ferric iron are required to completely metabolize 1 mg of benzene. Alternatively, the mass ratio of ferrous iron produced during benzene biodegradation through iron reduction is given by:

$$\text{Benzene} \quad 6(12) + 6(1) = 78 \text{ gm}$$

$$\text{Ferrous Iron} \quad 30(55.85) = 1675.5 \text{ gm}$$

$$\text{Mass ratio of ferrous iron to benzene} = 1675.5/78 = 21.5:1$$

Therefore, 21.5 mg of ferrous iron are produced during mineralization of 1 mg of benzene.

Similar calculations can be completed for toluene (21.86 mg of Fe^{2+} produced during mineralization of 1 mg of toluene), ethylbenzene (22 mg of Fe^{2+} produced during mineralization of 1 mg of ethylbenzene), and the xylenes (22 mg of Fe^{2+} produced during mineralization of 1 mg of xylene). The average mass ratio of Fe^{2+} produced during total BTEX mineralization is thus 21.8:1. This means that approximately 1 mg of BTEX is mineralized for every 21.5 mg of Fe^{2+} produced. The highest measured Fe^{2+} concentration was 44.0 mg/L. This suggests that the shallow groundwater at this site has the capacity to assimilate 2.02 mg/L (2,020 $\mu\text{g/L}$) of total BTEX during iron reduction. This is a conservative estimate of the assimilative capacity of iron because microbial cell mass production has not been taken into account by the stoichiometry shown above (see Section 4.3.2.1). In addition, this calculation is based on observed ferrous iron concentrations and not on the amount of ferric hydroxide available in the aquifer. Therefore, the iron assimilative capacity of site groundwater could be much higher.

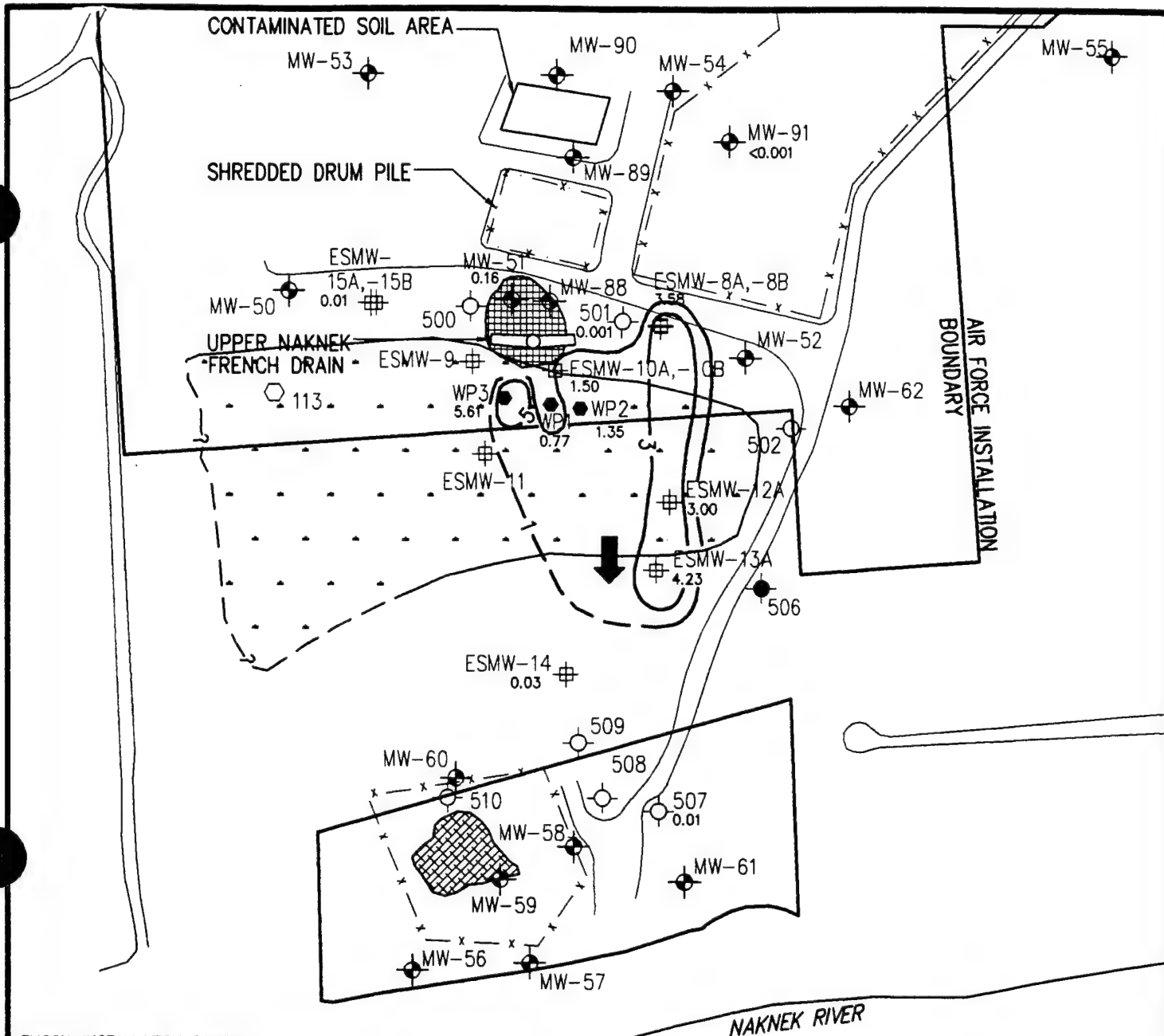
4.3.2.4 Sulfate

Sulfate concentrations were measured at groundwater monitoring wells in September 1994. Sulfate concentrations are very low and range from <0.5 mg/L to 8.54 mg/L. Table 4.4 summarizes measured sulfate concentrations. Sulfate concentrations are low and sulfate concentrations exhibit no definable pattern showing reduced sulfate concentrations in areas of high BTEX concentration. Sulfate does not appear to be an important electron acceptor for the biodegradation of fuels at the site.

4.3.2.5 Methane in Groundwater

Methane concentrations were measured at groundwater monitoring wells in June 1994. Table 4.4 summarizes methane concentrations. Figure 4.7 is an isopleth map showing the distribution of methane in groundwater. Comparison of Figures 4.2 and 4.7 shows graphically that some areas with elevated total BTEX concentrations (i.e., directly downgradient of the center of the eastern and western plumes) correlate with elevated methane concentrations. This is a strong indication that anaerobic biodegradation of the BTEX compounds is occurring at select locations at the site. This is consistent with other electron acceptor data, with the areas having elevated methane concentrations corresponding to the areas with depleted DO and elevated ferrous iron concentrations.

Methane concentrations ranged from 0.001 mg/L to 5.612 mg/L. Background levels of methane at wells outside areas with known BTEX contamination are below 0.011 mg/L. Samples collected from monitoring wells located near, or downgradient from the area with the



EMCON-INSTALLATION SAMPLING LOCATIONS

- 113 ○ WELL POINT (LFI)
- 507 ○ A-AQUIFER MONITORING WELL WITH METHANE CONCENTRATION (mg/L)
- 506 ● B-AQUIFER MONITORING WELL
- GROUNDWATER FLOW DIRECTION
- FENCE

SAMPLING LOCATIONS INSTALLED PRIOR TO FALL 1993

- MW-51 ● MONITORING WELL WITH METHANE CONCENTRATION (mg/L)
- WP3 ● MONITORING POINT WITH METHANE CONCENTRATION (mg/L)

SAMPLING LOCATIONS INSTALLED SEPTEMBER 1994

- ESMW-12A ● MONITORING WELL WITH METHANE CONCENTRATION (mg/L)
- ND NOT DETECTED
- AREA EXCAVATED IN 1992
- FORMER PRODUCT SEEP
- WETLANDS AREA (DASHED WHERE ESTIMATED)
- 3 — LINE OF EQUAL METHANE CONCENTRATION (mg/L)
- CONTOUR INTERVAL = 2 mg/L



FIGURE 4.7

METHANE ISOPLETH MAP FOR SHALLOW GROUNDWATER

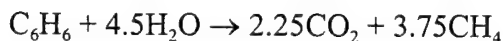
Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska

**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

highest BTEX concentrations contain the highest methane concentrations. The highest methane concentration observed at the site was at WP3, with elevated concentrations also present in wells ESMW-10A, ESMW-12A, ESMW-13A, WP1, and WP2.

The following equations describe the overall stoichiometry of benzene oxidation by methanogenesis. In the absence of microbial cell production, the mineralization of benzene is given by:



The mass ratio of methane produced during respiration to benzene degraded can be calculated and is given by:

Benzene	$6(12) + 6(1) = 78 \text{ gm}$
Methane	$3.75(16) = 60 \text{ gm}$

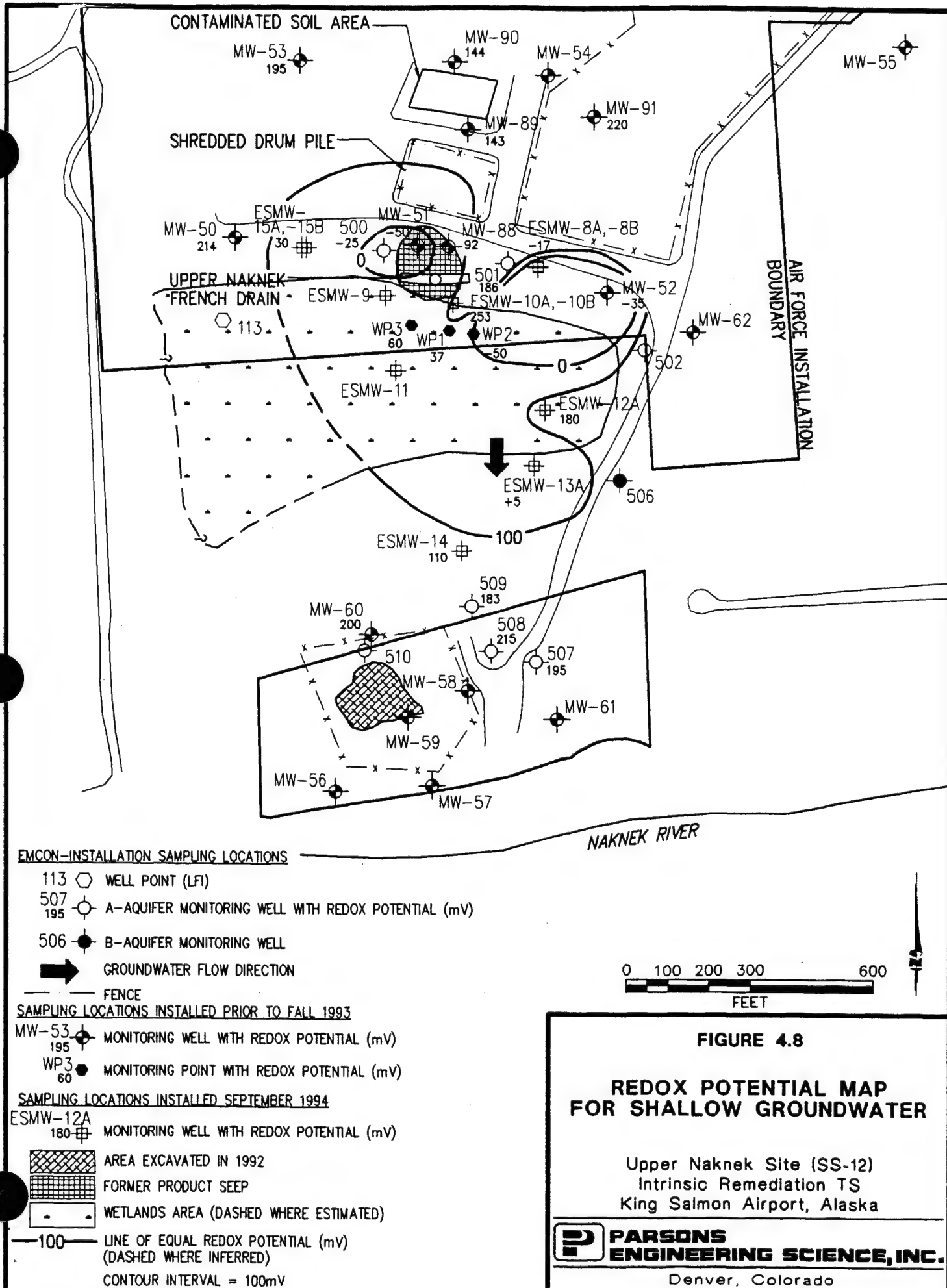
$$\text{Mass ratio of methane to benzene} = 60/78 = 0.77:1$$

Therefore, 0.77 mg of methane is produced during mineralization of 1 mg of benzene.

Similar calculations can be completed for toluene (0.78 mg of methane produced during mineralization of 1 mg of toluene), ethylbenzene (0.79 mg of methane produced during mineralization of 1 mg of ethylbenzene), and the xylenes (0.79 mg of methane produced during mineralization of 1 mg of xylene). The average mass ratio of methane produced during total BTEX mineralization is 0.78:1. This means that approximately 1 mg of BTEX is mineralized for every 0.78 mg of methane produced. The highest measured methane concentration was 5.612 mg/L. This suggests that the shallow groundwater at this site has the capacity to assimilate up to 7.19 mg/L (7,190 $\mu\text{g/L}$) of total BTEX during methanogenesis. Again, this is a conservative estimate of the assimilative capacity of methanogenesis because microbial cell mass production is not taken into account by the stoichiometry shown above (see Section 4.3.2.1). Moreover, these calculations are based on observed methane concentrations and not on the amount of carbon dioxide available in the aquifer. Therefore, methanogenic assimilative capacity could be much higher.

4.3.2.6 Reduction/Oxidation Potential

Redox potentials were measured at groundwater monitoring wells in September 1994. Redox potential is a measure of the relative tendency of a solution to accept or transfer electrons. The redox potential of a groundwater system depends on which electron acceptor is being reduced by microbes during BTEX oxidation. The redox potential in the surface aquifer at the Upper Naknek Site ranges from 255 millivolts (mV) to -50 mV. Table 4.4 summarizes available redox potential data. Figure 4.8 is a map that graphically illustrates the distribution of redox potentials. In general, redox potentials are below 0 mV in the vicinity of the plume center on the eastern and western plumes. As expected, areas at the site with low redox potentials coincide with areas of high BTEX contamination, low DO, and elevated ferrous iron and methane concentrations (compare Figure 4.8 with Figures 4.2, 4.4, 4.6, and 4.7).



4.3.2.7 Volatile Fatty Acids

At all groundwater sampling locations, EPA researchers collected samples for volatile fatty acids analysis. This test is a gas chromatography/mass spectroscopy (GC/MS) method wherein the samples are compared to a standard mixture containing 13 phenols, 25 aliphatic acids, and 19 aromatic acids. Compounds in the standard mixture are representative of intermediate degradation byproducts produced during petroleum hydrocarbon biodegradation. EPA researchers reported that all groundwater samples contained some components of phenols and aliphatic and aromatic fatty acids. This provides further evidence of fuel hydrocarbon biodegradation. As an example, ESMW-8A had the following relative percentage of functional groups in a groundwater sample taken: 72.3 percent aliphatics, 4.6 percent phenols, 7.8 percent aromatics, 11.7 percent alkenyl/cycloalkylcarmonic acids, and 3.6 percent dienoid/cycloalkenylcarmonic acids. EPA correspondence regarding these analyses is presented along with analytical results in Appendix B.

4.3.2.8 Alkalinity

Total alkalinity (as calcium carbonate) was measured at groundwater monitoring wells in September 1994. These measurements are summarized in Table 4.4. Alkalinity is a measure of a groundwater's ability to buffer changes in pH caused by the addition of biologically generated acids. Total alkalinity at the site is in the low to moderate range for groundwater, varying from 12 mg/L as CaCO_3 at monitoring well 509 to 256 mg/L as CaCO_3 at monitoring well ESMW-8A. This amount of alkalinity should be sufficient to buffer potential changes in pH caused by biologically mediated BTEX oxidation reactions.

4.3.2.9 pH

pH was measured at groundwater monitoring points and existing monitoring wells in September 1994. These measurements are summarized in Table 4.4. The pH of a solution is the negative logarithm of the hydrogen ion concentration $[\text{H}^+]$. Groundwater pH at the Upper Naknek Site ranges from 5.7 to 7.7 standard units. This range of pH is within the optimal range for BTEX-degrading microbes.

4.3.2.10 Temperature

Groundwater temperature was measured at groundwater monitoring points and existing monitoring wells in June 1994. Table 4.4 summarizes groundwater temperature readings. Temperature affects the types and growth rates of bacteria that can be supported in the groundwater environment, with higher temperatures generally resulting in higher growth rates. Temperatures in the shallow aquifer varied from 4.0 degrees Celsius ($^{\circ}\text{C}$) to 9.8 $^{\circ}\text{C}$.

4.3.3 Expressed Assimilative Capacity

The data presented in the preceding sections suggest that mineralization of BTEX compounds is occurring through the microbially mediated processes of aerobic respiration, iron reduction, and methanogenesis. Based on the stoichiometry presented in these sections, the expressed BTEX assimilative capacity of groundwater at the Upper Naknek is at least 12,940 $\mu\text{g/L}$ (Table 4.5). The calculations presented in the earlier sections are conservative because they do not

account for microbial cell mass production. In addition, the measured concentrations of ferrous iron and methane may not be the maximum achievable.

The highest observed dissolved total BTEX concentration observed at the site was 5,260 µg/L. Based on the calculations presented in the preceding sections, and on site observations, groundwater at the Upper Naknek Site has sufficient assimilative capacity to degrade the observed dissolved BTEX and limit plume migration.

TABLE 4.5
EXPRESSED ASSIMILATIVE CAPACITY OF SITE GROUNDWATER
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

Electron Acceptor or Process	Expressed BTEX Assimilative Capacity (µg/L)
Dissolved Oxygen	3,730
Iron Reduction	2,020
Methanogenesis	7,190
Expressed Assimilative Capacity	12,940
Highest Observed Total BTEX Concentration, Sept.	5,260

SECTION 5

GROUNDWATER MODEL

5.1 GENERAL OVERVIEW AND MODEL DESCRIPTION

In order to help estimate degradation rates for dissolved BTEX compounds at the Upper Naknek Site and to help predict the future migration of these compounds, Parsons ES modeled the fate and transport of the dissolved BTEX plume. The modeling effort had three primary objectives: 1) to predict the future extent and concentration of the dissolved contaminant plume by modeling the combined effects of advection, dispersion, sorption, and biodegradation; 2) to assess the possible threat to potential downgradient receptors; and 3) to provide technical support for the natural attenuation remedial option at post-modeling regulatory negotiations. The model was developed using site-specific data and conservative assumptions about governing physical and chemical processes. Due to the conservative nature of the model input, the reduction in contaminant mass resulting from the process of natural attenuation is expected to exceed model predictions. This analysis is not intended to represent a baseline assessment of potential risks posed by site contamination.

The Bioplume II code was used to estimate the potential for dissolved BTEX migration and degradation by naturally occurring mechanisms operating at the Upper Naknek Site. The Bioplume II model incorporates advection, dispersion, sorption, and biodegradation to simulate contaminant plume migration and degradation. The model is based upon the USGS Method of Characteristics (MOC) two-dimensional (2-D) solute transport model of Konikow and Bredehoeft (1978). The model was modified by researchers at Rice University to include a biodegradation component that is activated by a superimposed DO plume. Based on the work of Borden and Bedient (1986), the model assumes a reaction between DO and BTEX that is instantaneous relative to the advective groundwater velocity. Bioplume II solves the USGS 2-D solute transport equation twice, once for hydrocarbon concentrations in the aquifer and once for a DO plume. The two plumes are combined using superposition at every particle move to simulate the instantaneous, biologically-mediated, reaction between hydrocarbons and oxygen.

In recent years it has become apparent that anaerobic processes such as denitrification, iron reduction, sulfate reduction, and methanogenesis can be important BTEX degradation mechanisms (Grbic'-Galic', 1990; Beller *et al.*, 1992; Edwards *et al.*, 1992; Edwards and Grbic'-Galic', 1992; Grbic'-Galic' and Vogel, 1987; Lovley *et al.*, 1989; Hutchins, 1991). Geochemical evidence exists that supports the occurrence of anaerobic biodegradation processes at the Upper Naknek Site (Section 4.3.2). However, aerobic biodegradation was the only biodegradation process considered in modeling BTEX fate and transport at the Upper Naknek Site. The following subsections discuss in detail the

input parameters, the model assumptions, the model calibration, and the simulation results.

5.2 CONCEPTUAL MODEL DESIGN AND ASSUMPTIONS

Prior to developing a groundwater model, it is important to determine if sufficient data are available to provide a reasonable estimate of aquifer conditions. In addition, it is important to ensure that any limiting assumptions can be justified. The most important assumption made when using the Bioplume II model is that oxygen-limited biodegradation is occurring at the site. The Bioplume II model assumes that the limiting factors for biodegradation are: 1) the presence of an indigenous hydrocarbon-degrading microbial population, and 2) sufficient background electron acceptor concentrations. Data and information presented in Sections 3 and 4 suggest that oxygen, ferric hydroxide, and carbon dioxide (methanogenesis) are being used as electron acceptors for aerobic and anaerobic biodegradation. As previously mentioned, only oxygen was used as an electron acceptor in the Bioplume II model presented herein.

Based on the data presented in Section 3, the shallow saturated zone was conceptualized and modeled as a shallow unconfined aquifer composed of fine- to medium-grained sand (Figures 3.3 and 3.4). The saturated thickness of the aquifer is estimated to vary from 7 to 20 feet, and the downgradient aquifer boundary and recipient of aquifer discharge is the Naknek River. The use of a 2-D model is appropriate at the Upper Naknek Site because the saturated interval is relatively homogenous, and the local flow system, as defined by groundwater elevation data and the underlying sandy clay aquitard, will likely prevent significant downward vertical migration of dissolved BTEX contamination. The source of contamination at the site is not clearly identified, although BTEX is believed to emanate from former UST or POL line locations. Contaminated soils at the site have not been remediated, and numerous USTs remain in operation. As a result, a continuing source factor has been incorporated to account for additional dissolution of BTEX into groundwater over time.

5.3 INITIAL MODEL SETUP

Where possible, the initial setup for this model was based on site data. Where site-specific data were not available (e.g., effective porosity), reasonable assumptions for the types of materials comprising the shallow aquifer were made based on widely accepted literature values. The following sections describe the basic model setup. Those Bioplume II model parameters that were varied during model calibration are discussed in Section 5.4.

5.3.1 Grid Design and Boundary Conditions

The maximum grid size for the Bioplume II model is limited to 20 columns by 30 rows. The dimension of each column and row can range from 0.1 to 999.9 feet. A 20-by 30-cell grid was used to model the Upper Naknek Site. Each grid cell was 70 feet long by 70 feet wide. The grid was oriented so that the longest dimension was parallel to the overall direction of groundwater flow. The grid encompasses the existing BTEX plume with sufficient space between the northern, eastern, and western boundaries to avoid potential numerical errors caused by contact between the boundary and the BTEX

plume. The model grid covers an area of 2.94 million square feet, or approximately 67 acres. The full extent of the model grid is indicated on Figure 5.1.

Model boundaries are mathematical statements that represent hydrogeologic boundaries, such as areas of specified head (i.e., surface water bodies or contour lines of constant hydraulic head) or specified flux. Hydrogeologic boundaries are represented by three mathematical statements that describe the hydraulic head at the model boundaries. These include:

- Specified-head boundaries (Dirichlet condition) for which the head is determined as a function of location and time only. Surface water bodies exhibit constant head conditions. Specified-head boundaries are expressed mathematically as:

$$\text{Head} = f(x, y, z, t)$$

where f is the function symbol, x , y , and z are position coordinates, and t is time.

- Specified-flow boundaries (Neumann conditions) for which the mathematical description of the flux across the boundary is given. The flux is defined as a volumetric flow rate per unit area (i.e., $\text{ft}^3/\text{ft}^2/\text{day}$). No-flow boundaries are a special type of specified flow boundary and are set by specifying the flux to be zero. Examples of no-flow boundaries include groundwater divides and impermeable hydrostratigraphic units. Specified-flux boundaries are expressed mathematically as:

$$\text{Flux} = f(x, y, z, t)$$

- Head-dependent flow boundaries (Cauchy or mixed-boundary conditions) where the flux across the boundary is calculated from a given boundary head value. This type of flow boundary is sometimes referred to as a mixed-boundary condition because it is a combination of a specified-head boundary and a specified-flow boundary. Head-dependent flow boundaries are used to model leakage across semipermeable boundaries. Head-dependent flow boundaries are expressed mathematically as (Bear, 1979):

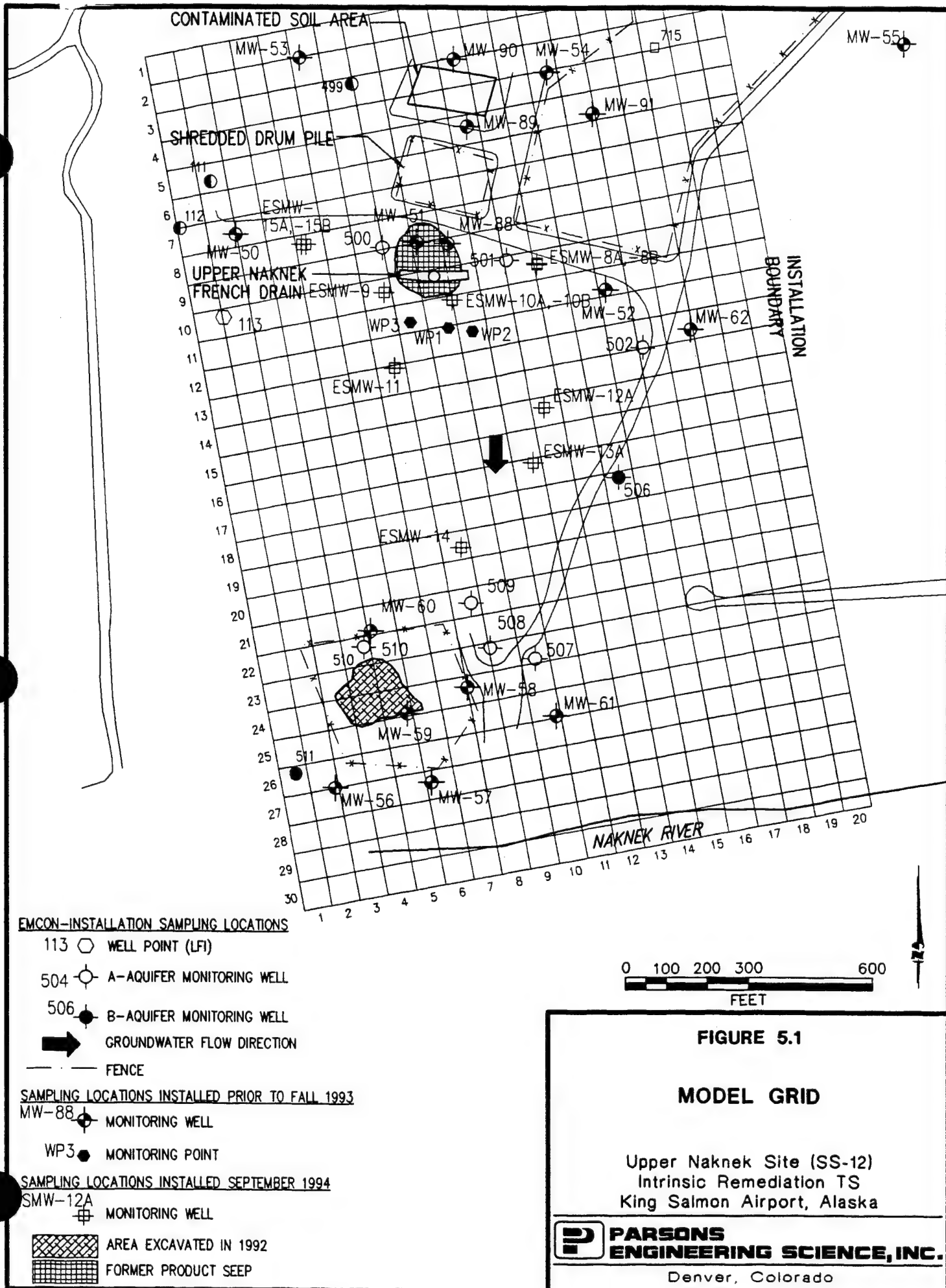
$$\text{Flux} = \frac{(H_0 - H)K'}{B'}$$

Where: H = Head in the zone being modeled (generally the zone containing the contaminant plume)

H_0 = Head in external zone (separated from plume by semipermeable layer)

K' = Hydraulic conductivity of semipermeable layer

B' = Thickness of semipermeable layer.



Natural hydraulic boundaries are modeled using a combination of the three types of model boundary conditions listed above. When possible, hydrologic boundaries such as surface water bodies, groundwater divides, contour lines, or hydrologic barriers should coincide with the perimeter of the model. In areas lacking obvious hydrologic boundaries, specified-head or specified-flux boundaries can be specified at the model perimeter if the boundaries are far enough removed from the contaminant plume that transport calculations are not affected. Bioplume II requires the entire model domain to be bounded by zero-flux cells (also known as no-flow cells), with other boundary conditions established within the subdomain specified by the no-flow cells.

Specified-head boundaries for the model were set on the northern and southern perimeter of the model grid to simulate groundwater flow to the south as observed at the site. The head of the northern boundary was estimated to be from 29.5 to 31.6 feet above msl. The southern model boundary was defined by water level contours near the bank of the Naknek River and ranged from 8.0 to 9.5 ft above msl.

The eastern and western model boundaries were configured as no-flow (specified-flux) boundaries. In this case, the flux through these boundaries is assumed to be zero because flow is generally parallel to these boundaries. The base or lower boundary of the model is also assumed to be no-flow, and is defined by the upper surface of the A-Aquitard. The upper model boundary is defined by the simulated water table surface.

5.3.2 Groundwater Elevation and Gradient

The water table elevation map presented in Figure 3.5 was used to define the starting heads input into the Bioplume II model. Groundwater flow in the vicinity of the Upper Naknek Site is to the south with a gradient range over the modeled area of approximately 0.02 ft/ft to 0.006 ft/ft. Gradients are lowest near the wetland on the western half of the model grid. Groundwater gradients are higher on the upper half of the model grid near the bluff that separates the Upper Naknek Plateau from the lower wetland.

Limited data exist to document any significant seasonal variations in groundwater flow direction. Considering the close proximity of the Naknek River and its influence on the direction of groundwater flow (i.e., flow should always be to the south), it was assumed that the observed water levels were representative of steady-state conditions. As described in Section 5.4.1, the model was calibrated to the observed water table.

5.3.3 BTEX Concentrations

The total dissolved BTEX concentrations obtained from laboratory analytical results for each well location were used for model development. At well nests, the highest BTEX concentration observed at that location was used as the representative concentration. Table 4.3 presents dissolved BTEX concentration data. Figure 4.2 shows the areal distribution of dissolved BTEX compounds in the A-Aquifer in September 1994.

The initial objective of Bioplume II modeling for the Upper Naknek Site was to study the fate and transport of the western BTEX plume. However, an eastern plume also emanating from the Upper Naknek Site merges with the western plume downgradient of the source areas to form the heart-shaped plume shown in Figure 4.2. Considering that

neither plume is distinguishable from the other at downgradient locations, Bioplume II modeling for this report included both plumes. The combined BTEX plume observed in September 1994 covers an area of approximately 495,000 square feet (11.4 acres). As described in Section 5.4.2, the simulated BTEX plume was calibrated to match the observed BTEX plume.

5.3.4 Dissolved Oxygen

As discussed previously, the Bioplume II model assumes an instantaneous reaction between the BTEX plume and the DO plume. The discussion presented in Section 4 suggests that DO, ferric iron, and carbon dioxide (methanogenesis) are being used as electron acceptors for biodegradation of BTEX compounds at the Upper Naknek Site. To be conservative, the total BTEX plume at the site was modeled assuming that DO was the only electron acceptor being utilized for the biodegradation of BTEX compounds at a rate that is instantaneous relative to the advective groundwater flow velocity.

Groundwater samples collected from contaminated and uncontaminated portions of the aquifer suggest that DO concentrations at the site range from 0.1 to 11.7 mg/L. Background oxygen concentrations recorded upgradient of soil contamination ranged from 10.5 to 11.7 mg/L at three well locations (MW-50, MW-53, and MW-90). The upgradient specified-head cells in the Bioplume II model require background DO concentrations to be input as constant concentrations to simulate incoming electron acceptors. A DO concentration of 11.7 mg/L was used at these specified-head cells. Table 4.4 contains DO data for the site. Figure 4.4 is a DO isopleth map. The concentrations of DO in the aquifer as shown in Figure 4.4 were input into the Bioplume II models as the starting DO concentrations in the modeled aquifer.

5.4 MODEL CALIBRATION

Model calibration is an important component in the development of any numerical groundwater model. Calibration of the flow model demonstrates that the model is capable of matching hydraulic conditions observed at the site; calibration of a contaminant transport model superimposed upon the calibrated flow model helps verify that contaminant loading and transport conditions are being appropriately simulated. The numerical flow model presented herein was calibrated by altering transmissivity in a trial-and-error fashion until simulated heads approximated observed field values within a prescribed accuracy. After calibration of the flow model, the numerical transport model was calibrated by altering transport parameters in a trial-and-error fashion until the simulated BTEX plume approximated observed field values. Table 5.1 lists input parameters used for the modeling effort. Model input and output are included in Appendix D.

5.4.1 Water Table Calibration

The shallow water table at the Upper Naknek Site was assumed to be influenced by two physical characteristics of the site: 1) continuous recharge and discharge at the constant-head cells established at the upgradient and downgradient model boundaries; 2) continuous recharge from annual precipitation at wetland locations. Recharge to wetland locations was included for a better hydraulic match of the model to site conditions. Wetland recharge was considered devoid of DO because of the high organic carbon

TABLE 5.1
BIOPLUME II MODEL INPUT PARAMETERS
UPPER NAKNEK SITE(SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

Parameter	Description	Calibrated Model Setup	Model Runs	
			NaknekA	NaknekB
NTIM	Maximum number of time steps in a pumping period	10	10	4, 2(x8)
NPMP	Number of Pumping Periods	1	1	9
NX	Number of nodes in the X direction	20	20	20
NY	Number of nodes in the Y direction	30	30	30
NPMAX	Maximum number of Particles $NPMAX = (NX-2)(NY-2)(NPTPND) + (Ns^*)(NPTPND) + 250$	5477	5477	5477
NPNT	Time step interval for printing data	1	1	1
NITP	Number of iteration parameters	7	7	7
NUMOBS	Number of observation points	0	0	0
ITMAX	Maximum allowable number of iterations in ADIP ^{b/}	200	200	200
NREC	Number of pumping or injection wells	13	13	13
NPTPND	Initial number of particles per node	9	9	9
NCODES	Number of node identification codes	1	1	1
NPNTMV	Particle movement interval (IMOV)	0	0	0
NPNTVL	Option for printing computed velocities	1	1	2
NPNTD	Option to print computed dispersion equation coefficients	0	1	0
NPDELC	Option to print computed changes in concentration	0	0	0
NPNCHV	Option to punch velocity data	0	0	0
NREACT	Option for biodegradation, retardation and decay	1	1	1
PINT	Pumping period (years)	10	10	4, 1 (x8)
TOL	Convergence criteria in ADIP	0.001	0.001	0.001
POROS	Effective porosity	0.25	0.25	0.25
BETA	Characteristic length (long. dispersivity; feet)	3.3	3.3	3.3
S	Storage Coefficient	0 (Steady-State)	0	0
TIMX	Time increment multiplier for transient flow	-	-	-
TINIT	Size of initial time step (seconds)	-	-	-
XDEL	Width of finite difference cell in the x direction (feet)	70	70	70
YDEL	Width of finite difference cell in the y direction (feet)	70	70	70
DLTRAT	Ratio of transverse to longitudinal dispersivity	0.33	0.33	0.33
CELDIS	Maximum cell distance per particle move	0.5	0.5	0.5
ANFCTR	Ratio of Tyy to Txx (1 = isotropic)	1	1	1
DK	Distribution coefficient	0.079	0.079	0.079
RHOB	Bulk density of the solid (grams/cubic centimeter)	1.6	1.6	1.6
THALF	Half-life of the solute	-	-	-
DEC1	Anaerobic decay coefficient (day ⁻¹)	-	-	-
DEC2	Reaeration coefficient (day ⁻¹)	0.01	0.01	0.01
F	Stoichiometric Ratio of Hydrocarbons to Oxygen	3.14	3.14	3.14

^{a/} Ns = Number of nodes that represent fluid sources (wells or constant head cells)

^{b/} ADIP = Alternating-direction implicit procedure (subroutine for solving groundwater flow equation)

content of the wetland water. A culvert located beneath the north/south road at the site connects the wetland below the Naknek Site to adjacent wetland terrain to the east. Other than the culvert, no other surface water channels exist to allow natural drainage of the wetland. As a result, wetland waters drain from the area through reentry into the aquifer or evaporation. Due to the typically low temperatures at the site, reentry to the aquifer was considered as the only migration pathway for wetland waters. The initial water levels at the constant-head cells and the transmissivity values were varied to calibrate the water table surface. The model was calibrated under steady-state conditions.

Hydraulic conductivity is an important aquifer characteristic that determines the ability of the water-bearing strata to transmit groundwater. Transmissivity is the product of the hydraulic conductivity and the thickness of the aquifer. An accurate estimate of hydraulic conductivity is important to help quantify advective groundwater flow velocities and to define the flushing potential of the aquifer and the quantity of electron-acceptor-charged groundwater that is entering the site from upgradient locations. According to the work of Rifai *et al.* (1988), the Bioplume II model is particularly sensitive to variations in hydraulic conductivity. Lower values of hydraulic conductivity result in a slower-moving plume that degrades at a slower rate because few electron acceptors are available for biodegradation at the contaminant source. Higher values of hydraulic conductivity result in a faster-moving plume that degrades faster because more electron acceptors are available for biodegradation at the contaminant source.

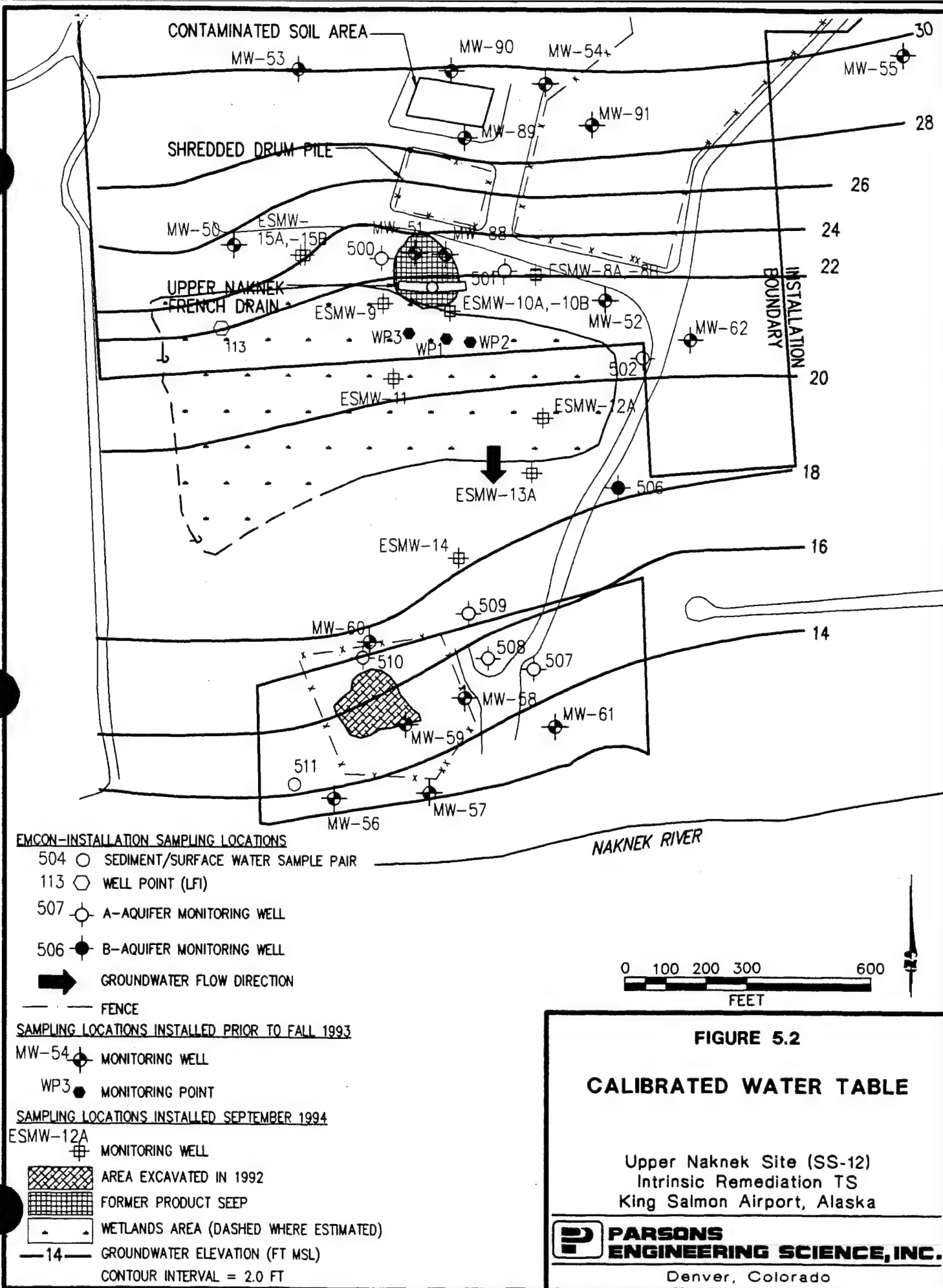
Saturated thickness data from previous reports, geologic logs, and water level measurements were used in conjunction with the hydraulic conductivity estimates to create an initial transmissivity grid for the entire model. To better match heads in the model to observed values, the transmissivities were progressively varied in blocks and rows until the simulated water levels for cells corresponding to selected well locations matched the observed water levels as closely as possible. Figure 5.2 shows the calibrated water table. Calibrated model hydraulic conductivities ranged from 4.0×10^{-5} foot per second (ft/sec) to 2.5×10^{-3} ft/sec (2.4×10^{-3} ft/min to 1.5×10^{-1} ft/min), within the range of previously estimated values of hydraulic conductivity for the site (Section 3.3.2.2).

Water level elevation data from cells associated with 18 monitoring well locations were used to compare measured and simulated heads for calibration. The 18 selected cell locations each contained one of the following wells: ESMW-8, ESMW-9, ESMW-10, ESMW-11, ESMW-12, ESMW-13, ESMW-14, ESMW-15, MW-50, MW-51, MW-52, MW-60, MW-88, MW-89, 500, 507, 508, and 509.

The root mean square (RMS) error is commonly used to express the average difference between simulated and measured heads. RMS error is the average of the squared differences between measured and simulated heads, and can be expressed as:

$$\text{RMS} = \left[\frac{1}{n} \sum_{i=1}^n (h_m - h_s)_i^2 \right]^{0.5}$$

Where: n = the number of points where heads are being compared
 h_m = measured head value
 h_s = simulated head value.



The RMS error between observed and calibrated values at the 18 comparison points was 0.38 foot, which corresponds to a calibration error of 1.73 percent (water levels dropped 22 feet over the length of the model grid). RMS error calculations are summarized in Appendix C. A plot of measured vs. calibrated heads shows a random distribution of points around a straight line, as shown in Appendix C. Deviation of points from a straight line should be randomly distributed in such a plot of results from computer simulations (Anderson and Woessner, 1992).

In solving the groundwater flow equation, Bioplume II establishes the water table surface and calculates an overall hydraulic balance that accounts for the numerical difference between flux into and out of the system. The hydraulic mass balance for the calibrated model was excellent, with 99.95 percent of the water flux into and out of the system being numerically accounted for (i.e., a 0.05-percent error). According to Anderson and Woessner (1992), a mass balance error of around 1 percent is acceptable, while Konikow (1978) indicates an error of less than 0.1 percent is ideal.

5.4.2 BTEX Plume Calibration

Model input parameters affecting the distribution and concentration of the simulated BTEX plume were modified so that model predictions matched dissolved total BTEX concentrations observed in September 1994. To do this, model runs were made using the calibrated steady-state hydraulic parameters coupled with the introduction of contaminants. Because the exact time of the spill is unknown, the model was calibrated to match September 1994 conditions, assuming that these conditions represent the maximum extent of BTEX contamination.

Owing to the lack of mobile LNAPL (with exception of thin LNAPL contamination at monitoring well 500) in monitoring wells or at the french drain, and low concentrations of BTEX in the vadose zone of the site, it is possible that site contamination is decreasing through natural weathering. Early signs of fuel contamination in soil and groundwater were evidenced by hydrocarbon sheens as early as 1985 (Engineering-Science, Inc., 1985). This means that JP-4 has contaminated the soil and groundwater at the site for at least the past 10 years. Furthermore, the typical groundwater velocity in the areas of highest groundwater contaminant concentrations is approximately 1.0×10^{-5} ft/s (0.86 ft/day), a rate that would allow groundwater to reach the Naknek River (about 1,500 feet downgradient) in roughly 5 years. Groundwater BTEX data show that hydrocarbon contamination extends to ESMW-13A, which is approximately 600 feet downgradient from the highest concentrations of groundwater contamination in the presumed source area. Therefore, the assumption used for the dissolved BTEX plume calibration that the existing plume represents the maximum likely extent of contamination is justified for three reasons: 1) mobile or residual LNAPL at the site is present in low concentrations, which suggests that the introduction of contamination has stopped or slowed, and contaminant loading rates will not likely increase; 2) mobile LNAPL is not discharging at noticeable rates from the product seep (i.e. the french drain); and 3) groundwater velocity data suggest that groundwater contamination should have migrated further downgradient than the observed plume front, even if contaminant retardation is considered.

Because residual LNAPL is assumed to be the main contaminant source at the site (mobile LNAPL was only detected in one well), it was necessary to include model injection wells to simulate partitioning of BTEX compounds from the residual phase into

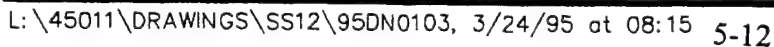
the groundwater. This transport pathway from residual soil contamination to groundwater occurs either through fluctuations in groundwater elevations that allow groundwater to contact contaminated soils, or through percolating precipitation that transports soil contamination to the water table. The locations of the injection wells are shown on Figure 5.3. Injection wells were placed based on soil contamination patterns; additional wells were placed as needed to reproduce the shape of the observed groundwater plume.

While the term "injection well" suggests contaminants are being introduced at a point, Bioplume II assumes that contamination introduced at a well instantly equilibrates throughout the entire cell in which the well is located. The injection rate for the cells was set at 5×10^{-5} cubic foot per second (ft^3/sec), a value low enough that the flow calibration and water balance was not affected. Relatively high BTEX concentrations were injected in upgradient injection wells because of the low injection rate and the influx of oxygen introduced at the upgradient constant head cells. Replenishment of oxygen quickly degraded BTEX concentrations at the head of the plume, which in turn required higher injection concentrations of BTEX to produce observed BTEX contours. Based on assumptions outlined in Section 5.3.4, it was assumed that initial DO concentrations in the shallow aquifer were as measured in September 1994. Background DO concentrations of 11.7 mg/L were continually introduced at the northern boundary of the model.

Total BTEX injection concentrations were determined by varying the injection concentration for the various wells until the modeled total BTEX plume approximated the total BTEX plume observed in September 1994. By varying the injection well concentrations, the coefficient of retardation, dispersivity, and the reaeration coefficient, the BTEX plume was calibrated reasonably well to the existing plume in terms of migration distance and BTEX concentrations in the source area. The calibrated plume configuration is shown on Figure 5.4.

Although the overall area and concentration of the modeled plume slightly exceed observed conditions, visual inspection of the calibrated model plume shows that it matches well with actual conditions. The objective of the calibration was to achieve a modeled plume that equaled or exceeded the existing plume in terms of concentration and extent after one year of simulated time. The downgradient extent of the computed $1\text{-}\mu\text{g/L}$ contour is similar to the observed $1\text{-}\mu\text{g/L}$ contour, and the area encompassed by the computed $5,000\text{-}\mu\text{g/L}$ BTEX contour in the eastern plume area is equivalent to the observed $5,000\text{-}\mu\text{g/L}$ contour. The maximum BTEX concentration in the plume after 1 year of simulated time is $7,800\text{-}\mu\text{g/L}$ at ESMW-8A, which is higher than observed 1994 concentrations. Steady-state conditions are reached after 4 years of simulated time and the maximum BTEX concentration in the source area stabilizes at $7,700\text{-}\mu\text{g/L}$. The fact that the model concentrations and plume extent at steady-state are greater than observed means that predictions based on this simulation will be conservative.

The joining of the observed western and eastern BTEX plume was reproduced well during model calibration. This was in large part due to the calibration of the groundwater table, which effectively reproduces the flow within the shallow aquifer. Any variations in shape between the model and the observed plume likely are due to subsurface heterogeneities with hydraulic conductivity, reaeration coefficient, dispersivity, and



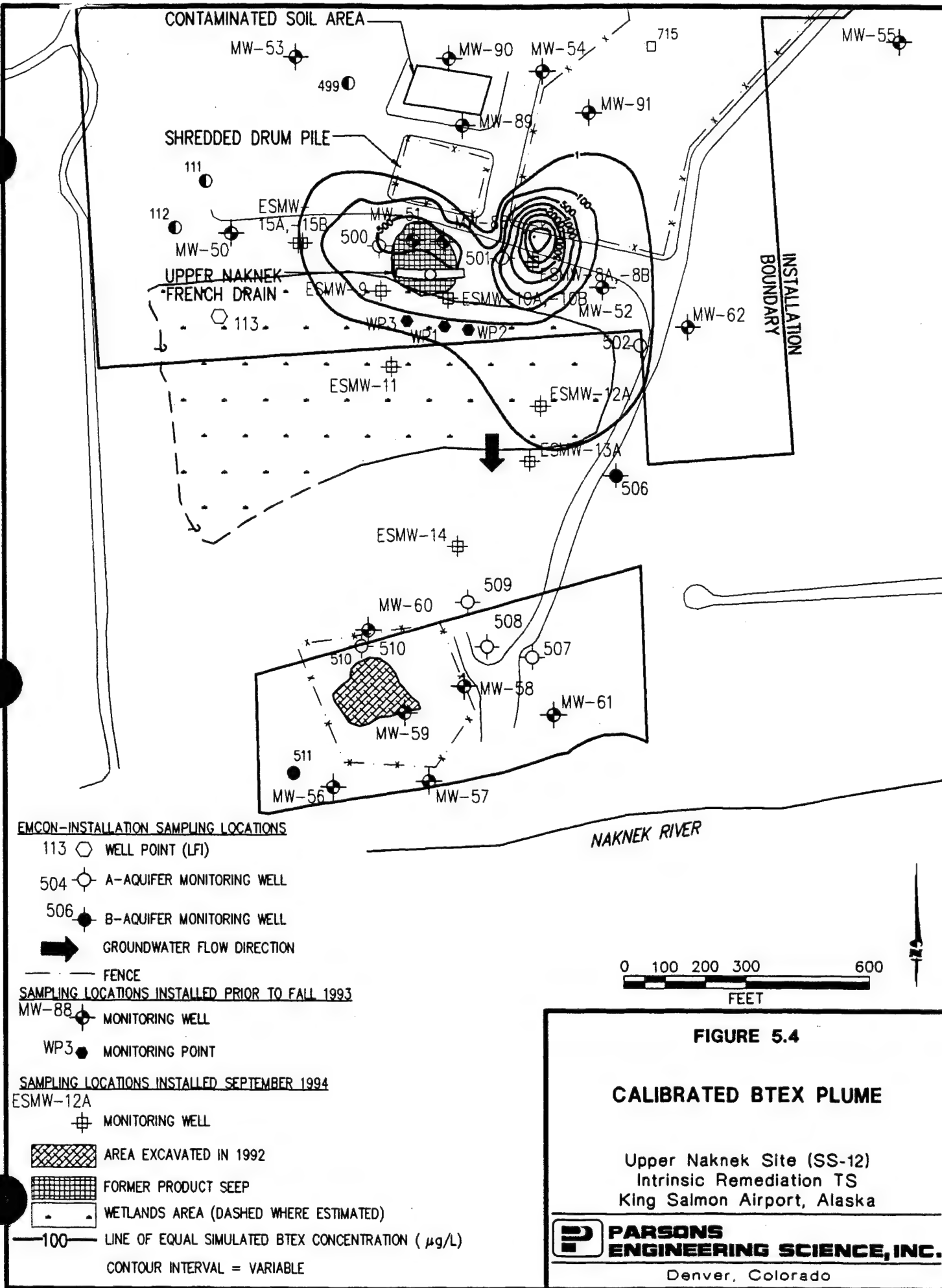


FIGURE 5.4

CALIBRATED BTEX PLUME

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska

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Denver, Colorado

retardation coefficient that are extremely difficult to identify in the field and in a discretized model domain.

5.4.2.1 Discussion of Parameters Varied During Plume Calibration

As noted previously, the transport parameters varied during plume calibration were dispersivity, the coefficient of retardation, and the reaeration coefficient. Those parameters were generally varied with intent of altering plume migration so that the observed plume extent was reproduced. While these parameters were varied with this common intent, each had a slightly different impact on the size and shape of the simulated plume.

5.4.2.1.1 Dispersivity

Much controversy surrounds the concepts of dispersion and dispersivity. Longitudinal dispersivity values for sediments similar to those found at the site range from 0.1 to 200 feet (Walton, 1988). Longitudinal dispersivity was originally estimated as 3.3 feet, using one-tenth (0.1) of the distance between the estimated spill source of the western plume and the longitudinal centroid of the western plume (see Figure 4.2). Dispersivity estimation calculations are included in Appendix C. Transverse dispersivity values generally are estimated as one-tenth (0.1) of the longitudinal dispersivity values (Domenico and Schwartz, 1990).

During plume calibration, longitudinal dispersivity was maintained at 3.3 feet. This value is low compared to possible values that could have been used, but is justified by the calculations in Appendix C. Furthermore, the use of a low dispersivity value is a conservative estimate for modeling because low dispersivities cause less BTEX to be lost to dilution. At the same time, the ratio of transverse dispersivity to longitudinal dispersivity was maintained at 0.33 to help reproduce the plume width observed at the site.

5.4.2.1.2 Coefficient of Retardation

Retardation of the BTEX compounds relative to the advective velocity of the groundwater occurs when BTEX molecules are sorbed to the aquifer matrix. The coefficients of retardation for the BTEX compounds were calculated based on measured TOC concentrations in the soils in and near the saturated zone at the site, an assumed bulk density of 1.6 grams/cubic centimeter (Freeze and Cherry, 1979), and published values of the soil sorption coefficient (K_{oc}) for the BTEX compounds, as listed by Wiedemeier *et al.* (1994). The results of these calculations are summarized in Table 5.2. Because available TOC data were limited to three locations that were not considered representative of background conditions, TOC was given an assumed value of 0.1 percent. This low value is within the range of TOC concentrations recorded at the site. A final value of 1.51 for the retardation coefficient (compared to calculated retardation coefficients of 1.1 to 8.91) was used for the BTEX compounds, and is intended to be reflective of benzene, which is the least sorptive BTEX compound. During plume calibration, the initial coefficient of retardation was initially set at 1.10 and was gradually raised to the calibrated value of 1.51. As with dispersivity and the reaeration coefficient, this variable was adjusted in response to model predictions of BTEX concentrations extending beyond the observed limits.

TABLE 5.2
CALCULATION OF RETARDATION COEFFICIENTS
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

Compound	K_{oc} (L/kg ^{a/})	Maximum Fraction Organic Carbon ^{b/}	Minimum Fraction Organic Carbon ^{b/}	Average Fraction Organic Carbon ^{b/}	Distribution Coefficient K_d (L/kg)			Bulk Density (kg/L) ^{d/}	Effective Porosity	Coefficient of Retardation	
					Maximum ^{c1/}	Minimum ^{c2/}	Average ^{c3/}			Maximum	Average
Benzene	79	0.01878	0.00024	0.00859	1.484	0.019	0.679	1.60	0.30	8.91	4.62
Toluene	190	0.01878	0.00024	0.00859	3.568	0.046	1.632	1.60	0.30	20.03	9.70
Ethylbenzene	468	0.01878	0.00024	0.00859	8.789	0.112	4.020	1.60	0.30	47.87	22.44
m-xylene	405	0.01878	0.00024	0.00859	7.606	0.097	3.479	1.60	0.30	41.56	19.55
o-xylene	422	0.01878	0.00024	0.00859	7.925	0.101	3.625	1.60	0.30	43.27	20.33
p-xylene	357	0.01878	0.00024	0.00859	6.704	0.086	3.067	1.60	0.30	36.76	17.36

NOTES:

^{a/} From technical protocol document (Wiedemeier *et al.*, 1994).

^{b/} From Upper Naknek data.

^{c1/} K_d = Maximum Fraction Organic Carbon x K_{oc} .

^{c2/} K_d = Minimum Fraction Organic Carbon x K_{oc} .

^{c3/} K_d = Average Fraction Organic Carbon x K_{oc} .

^{d/} Literature values.

5.4.2.1.3 Reaeration Coefficient

The reaeration coefficient is a first-order rate constant used in Bioplume II to simulate the replenishment of oxygen into the groundwater by soil gas diffusion and precipitation infiltration. A reaeration coefficient of 0.003 day^{-1} was originally estimated, based on other documented Bioplume modeling efforts (see, for example, Rifai *et al.*, 1988). Use of the reaeration coefficient is justified at this site because of the shallow water table and the relatively high DO concentrations observed in background groundwater.

The reaeration coefficient had a significant effect on limiting plume migration, and was also important in controlling the concentrations at the fringes of the plume. At its originally estimated value of 0.003 day^{-1} , the simulated plume extended much farther than the observed plume. This coefficient was gradually increased to 0.01 day^{-1} to match the observed plume in terms of downgradient extent. Appendix C contains estimates of first-order rate constants that can be used to estimate the reaeration coefficient. These reaeration coefficient estimates are based on first-order assumptions of hydrocarbon and oxygen loss, and on instantaneous reactions between introduced DO and hydrocarbons in the model as presented by Borden and Bedient (1986) and Rifai *et al.* (1988).

5.5 SENSITIVITY ANALYSIS

The purpose of the sensitivity analyses is to determine the effect of varying model input parameters on model output. Based on the work of Rifai *et al.* (1988), the Bioplume II model is most sensitive to changes in the coefficient of reaeration, the coefficient of anaerobic decay, and the hydraulic conductivity of the media, and is less sensitive to changes in the retardation factor, porosity, and dispersivity. A coefficient of anaerobic decay was not applied for Upper Naknek Site modeling. Because the porosity was not varied and the dispersivity was not significantly changed, the sensitivity analysis was conducted by varying the transmissivity, the reaeration coefficient, and the coefficient of retardation.

To perform the sensitivity analyses, the calibrated model was adjusted by systematically changing the aforementioned parameters individually, and then comparing the new model runs to the original calibrated model. The sensitivity models were run for a 10-year period to reach steady-state conditions and to assess the independent effect of each variable. As a result, six sensitivity runs of the calibrated model were made, with the following variations:

- 1) Transmissivity uniformly increased by a factor of 5;
- 2) Transmissivity uniformly decreased by a factor of 5;
- 3) Coefficient of reaeration increased by a factor of 2;
- 4) Coefficient of reaeration decreased by a factor of 2;
- 5) Coefficient of retardation increased by 35 percent; and,
- 6) Coefficient of retardation decreased by 35 percent.

The results of the sensitivity analyses are shown graphically in Figures 5.5, 5.6, and 5.7. These figures display the modeled BTEX concentrations versus distance along the centerline of the eastern plume (13th model grid column). This manner of displaying data is useful because BTEX concentrations are highest in the 13th column, and the eastern plume extends the farthest downgradient from the source of contamination. Furthermore, the plume generally migrates in a direction parallel to the model grid, and the figures allow easy visualization of the changes in BTEX concentration caused by varying model input parameters.

The effects of varying transmissivity are shown by Figure 5.5. Uniformly increasing the transmissivity by a factor of five increased the biodegradation rate of the plume such that the maximum observed concentrations in the source cell area were only about 1,600 $\mu\text{g/L}$, compared to the steady-state maximum of 7,700 $\mu\text{g/L}$. In this case, the BTEX plume extended to the Naknek River at concentrations below 7.5 $\mu\text{g/L}$ although this is not readily apparent in Figure 5.5. Lower BTEX concentrations in the center of the plume result from the greater flux of water through the model area bringing a greater mass of DO into contact with the plume. Because more electron acceptors are available, biodegradation occurs more rapidly. Also, the faster groundwater velocity produced by the higher transmissivity initially results in greater plume travel rates and distances, further exposing the BTEX to oxygenated water and greater dilution. In contrast, decreasing the transmissivity by a factor of five slowed overall plume migration, which shortened the plume by approximately 140 feet and in turn caused an increase in maximum BTEX levels. Increased BTEX concentrations in the plume area are caused by a reduction in the plume travel rate and the amount of oxygen being brought into contact with the contaminants from upgradient locations.

The effects of varying the reaeration coefficient are illustrated by Figure 5.6. Increasing this parameter by a factor of two results in a slightly smaller plume with maximum BTEX concentrations approximately 1,500 $\mu\text{g/L}$ lower than the calibrated model. In addition, the front of the plume receded approximately 420 feet, though this is not apparent by in the chart. This is a result of increased biodegradation. Conversely, decreasing the coefficient of reaeration by a factor of two decreases biodegradation and increases the length of the plume by 300 feet. The corresponding increase in the computed maximum BTEX concentrations in the plume center was approximately 1,100 $\mu\text{g/L}$.

The effects of varying the coefficient of retardation (R) are shown on Figure 5.7. Increasing R by 35 percent has a fairly significant effect on the contaminant distribution. Due to the increase in sorption in the model, the maximum BTEX concentration is nearly 80 percent lower and the plume is approximately 210 feet shorter than in the calibrated model. The decrease in plume extent and concentration resulted from slowing of BTEX migration, which allowed for greater contact of the sorbed BTEX with upgradient waters that were rich with DO. Decreasing R by 35 percent accelerated plume migration, which allowed for less contact of sorbed BTEX with upgradient, DO-rich waters flushing into the aquifer. With increased retardation coefficients, reaeration and dispersion become the dominant mechanisms of BTEX destruction. Because the retardation factor used for the model is low relative to other possible retardation factors (Table 5.2), the R used for the calibrated simulation is more conservative and produces acceptable results.

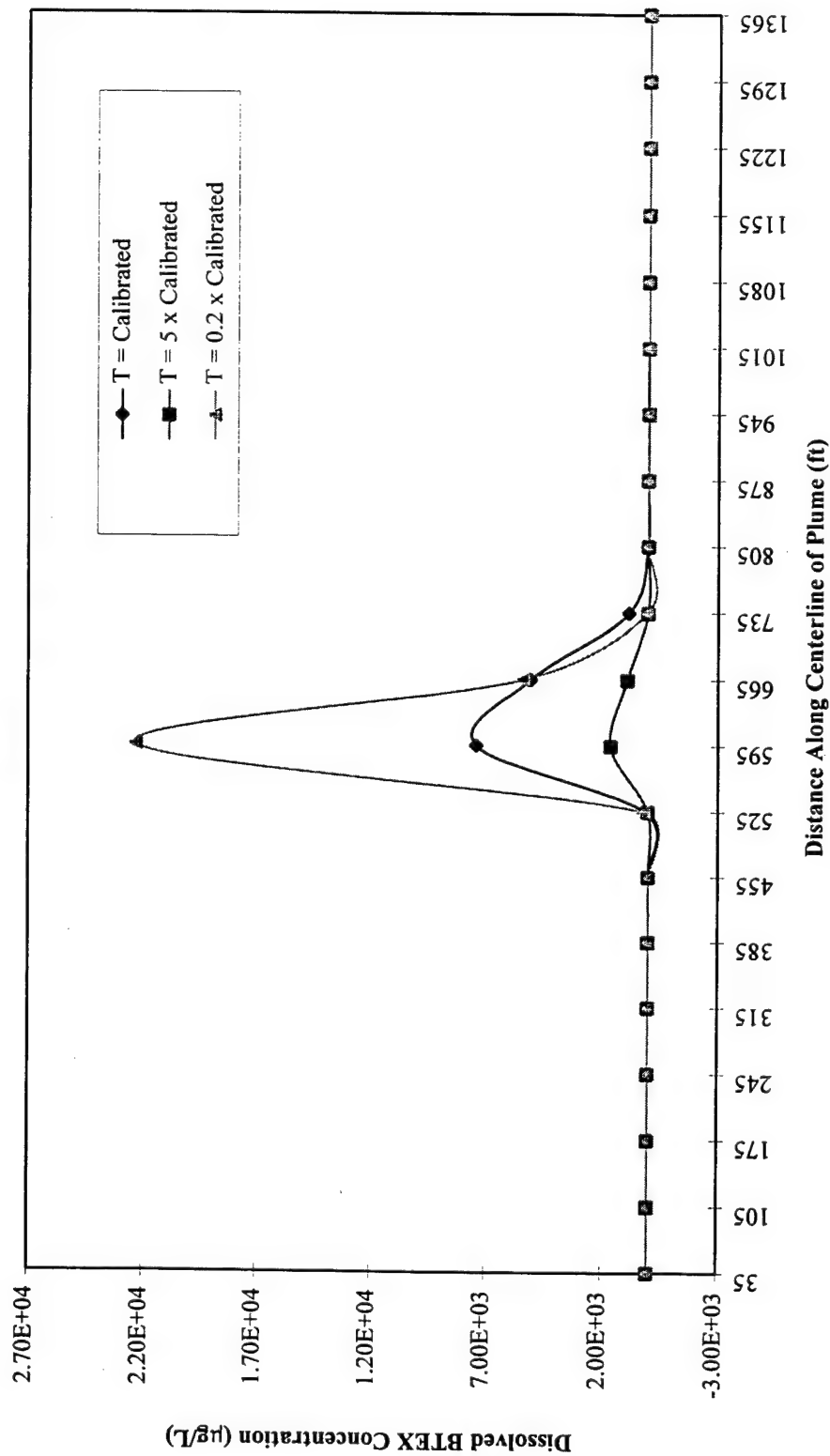


FIGURE 5.5

**MODEL SENSITIVITY
TO VARIATIONS IN
TRANSMISSIVITY**

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska



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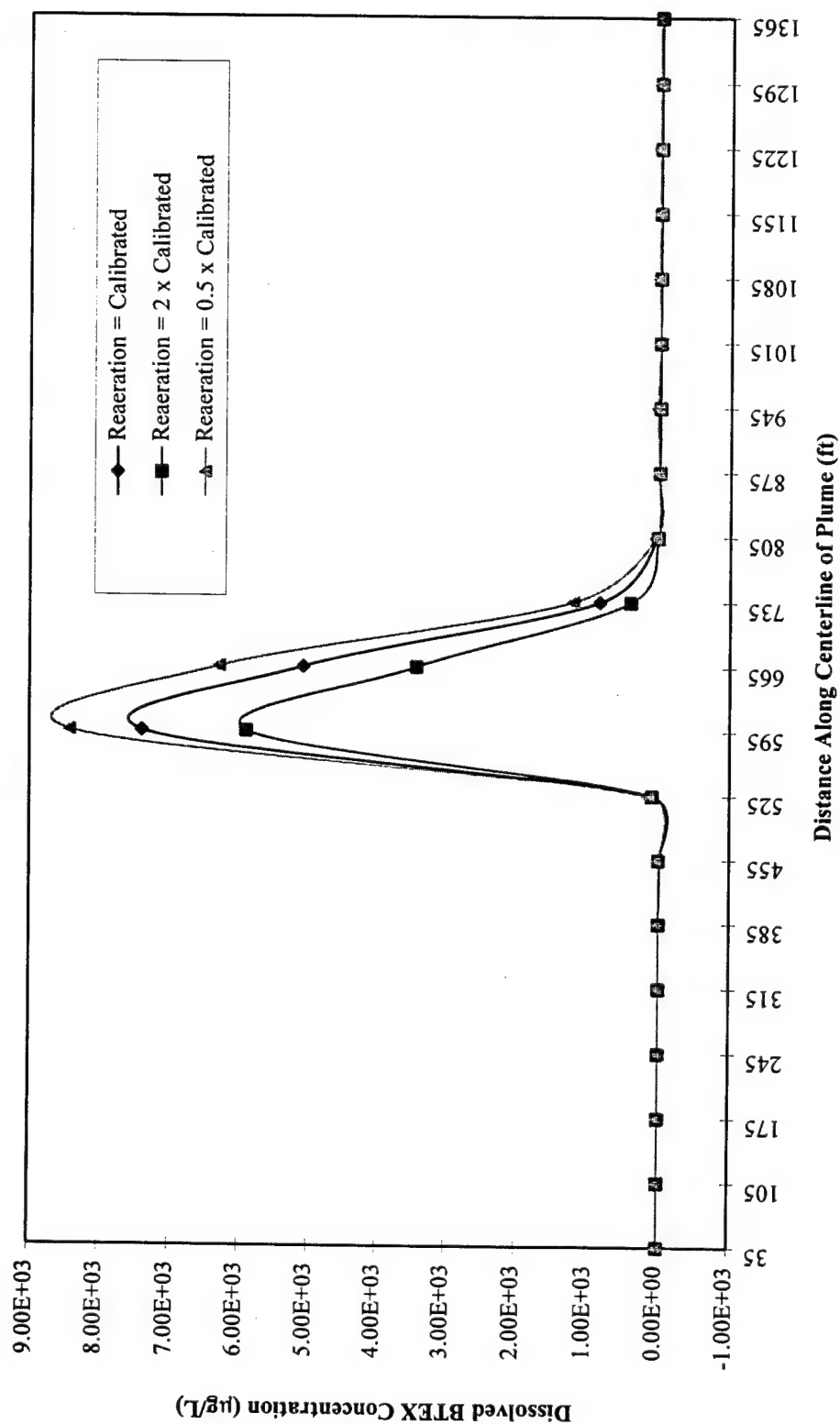


FIGURE 5.6

**MODEL SENSITIVITY TO
VARIATIONS IN REAERATION
COEFFICIENT**

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska



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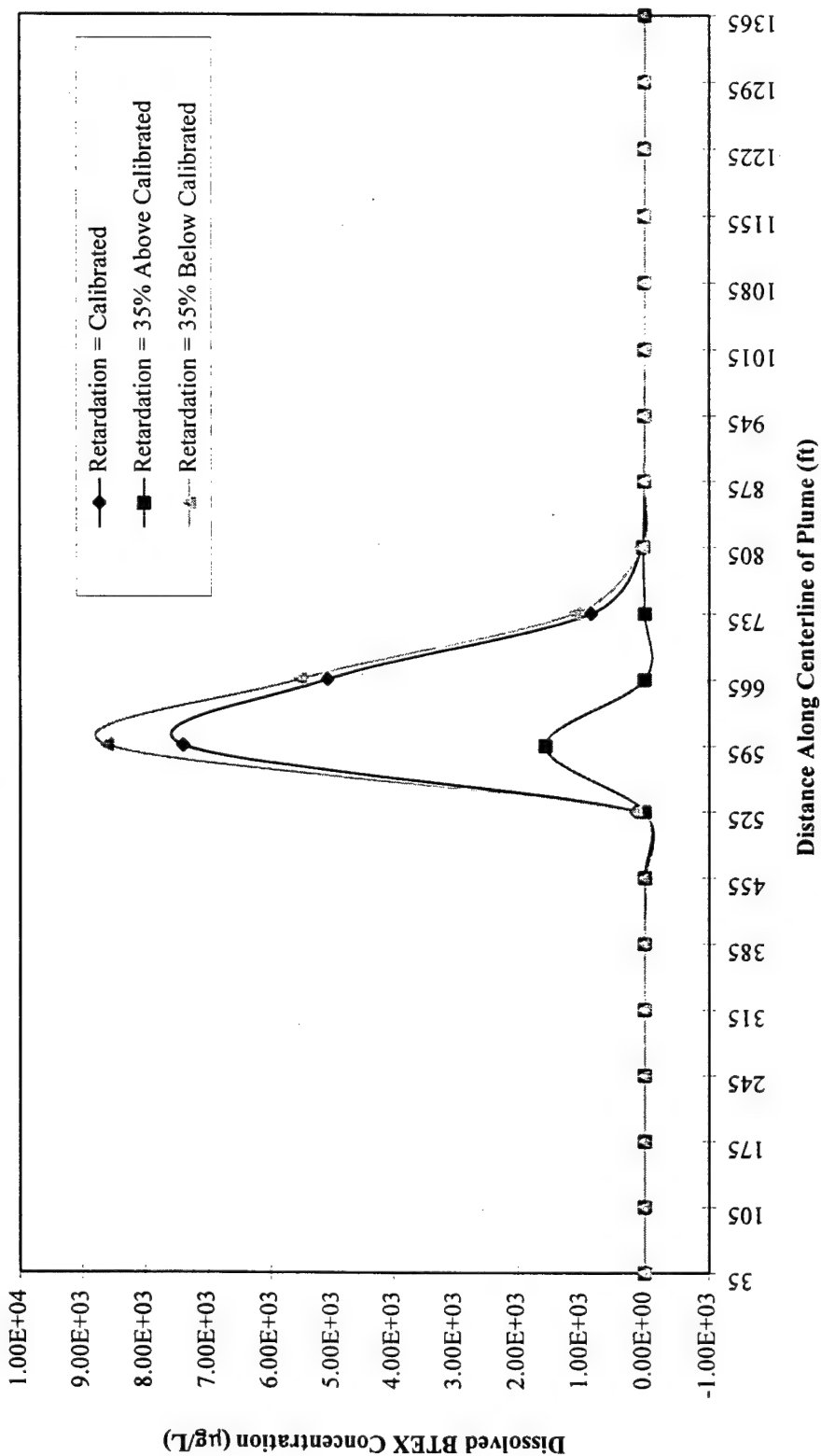


FIGURE 5.7

MODEL SENSITIVITY TO VARIATIONS IN RETARDATION COEFFICIENT

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska



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Denver, Colorado

The results of the sensitivity analyses suggest that the calibrated model parameters used for this report are reasonable. The calibrated model is very sensitive to all the parameters varied, and especially sensitive to transmissivity and the reaeration coefficient. Increasing transmissivities, the retardation factor, or the reaeration coefficient reduced the predicted BTEX concentrations in the source area. Lowering the values of the reaeration coefficient and the coefficient of retardation tended to lengthen the plume beyond reasonable distances based on recent observations at the site.

5.6 MODEL RESULTS

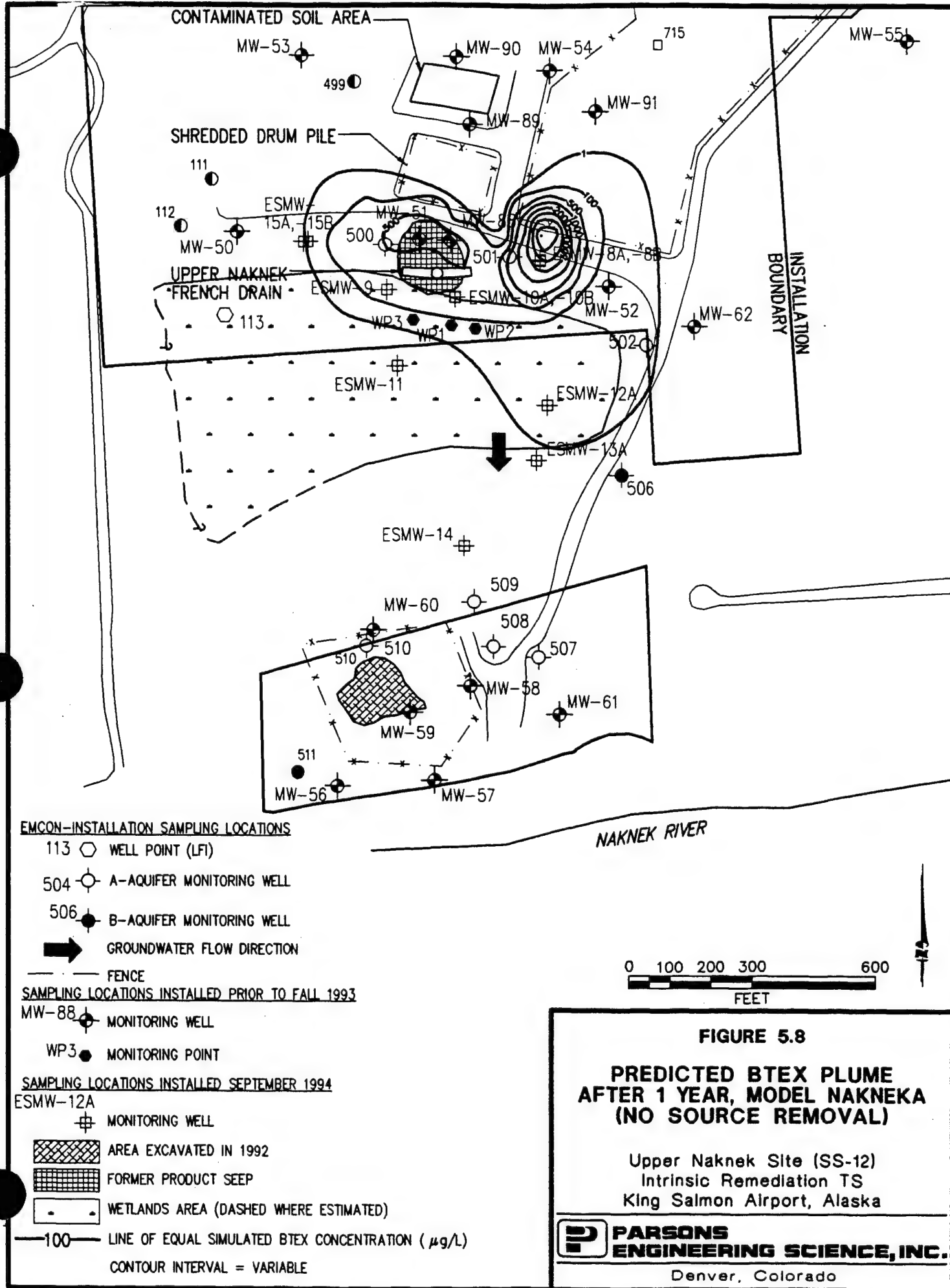
To predict fate and transport of dissolved BTEX compounds at the Upper Naknek Site, two Bioplume II simulations (NaknekA and NaknekB) were run under steady-state conditions. The first simulation assumed that the conditions used to calibrate the model continue indefinitely, so that current rates of BTEX partitioning from soil into groundwater neither increase or decrease. The second simulation assumed that through processes such as installation of a bioventing unit, and/or continued weathering of soil contamination, soil contamination is reduced 10 percent per year for 5 years, so that after 5 years, the BTEX loading rates are reduced to 50 percent of the calibrated rates. Complete input and output files are presented in Appendix D. Model results are described in the following sections.

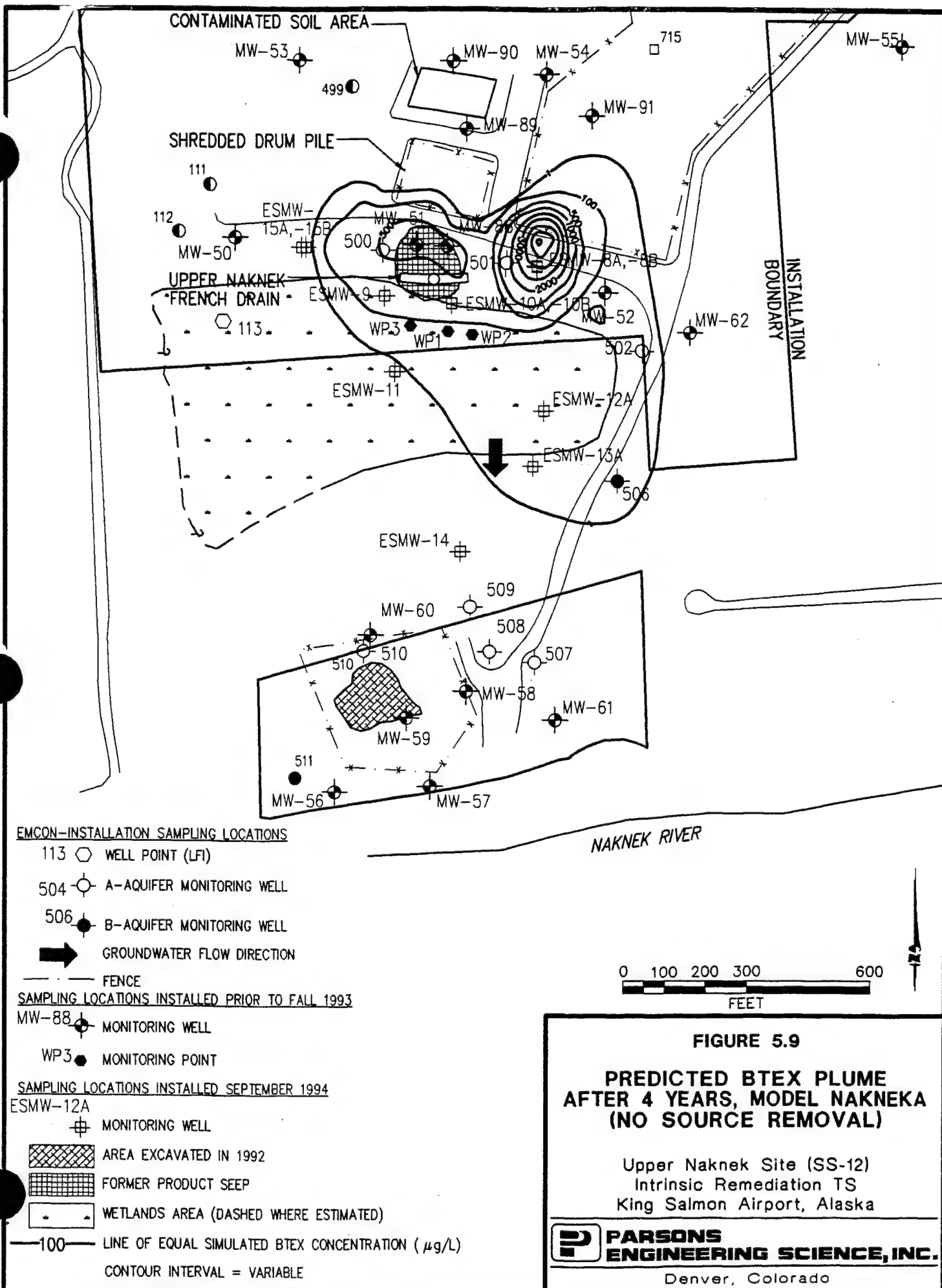
5.6.1 Continuation of Calibrated Conditions (Model NaknekA)

Model NaknekA was used to simulate the migration and biodegradation of the BTEX plume assuming that the conditions that produced the calibrated model continue, including a continuing source of dissolved BTEX compounds. The calibrated simulation was run to predict conditions over a 10-year period, but was configured to achieve September 1994 conditions (considered equilibrium conditions for this model) nearly instantaneously. For model NaknekA, the output from each year of the calibrated model was reviewed. These results suggest that the BTEX plume has already stabilized. Rapid equilibrium conditions were achieved by using September 1994 DO and BTEX concentrations for the setup of model NaknekA. Figure 5.8 shows the plume after 1 year of prediction time. The highest modeled BTEX concentrations are approximately 7,800 µg/L (above observed concentrations) and the plume (as defined by the 1-µg/L isopleth) closely approximates the observed plume shape (Figure 4.2).

Beyond 1 year of prediction time, model results show a slight increase in the plume extent, and the front of the modeled plume stabilizes about 150 feet farther downgradient than in year one. BTEX concentrations in the source areas remain higher than observed conditions (as high as 7,700 µg/L). These increased concentrations resulted from the injection rates necessary to approximate the observed plume. Figure 5.9 illustrates the stabilized BTEX plume after 4 years of prediction time, which is very similar to the year 1 simulation and suggests stabilization of the model plume.

Throughout the simulation, the maximum concentrations in the source area fluctuate in a regular pattern, suggesting that there may be a mathematical instability in the finite difference solution of this problem. However, the modeled extent of the plume is fairly stable and indicates that with continuous BTEX loading, the plume is not likely to extend more than 150 feet beyond the September 1994 plume front. Despite the fluctuations in plume concentration, the model is still useful because it predicts a stable plume with





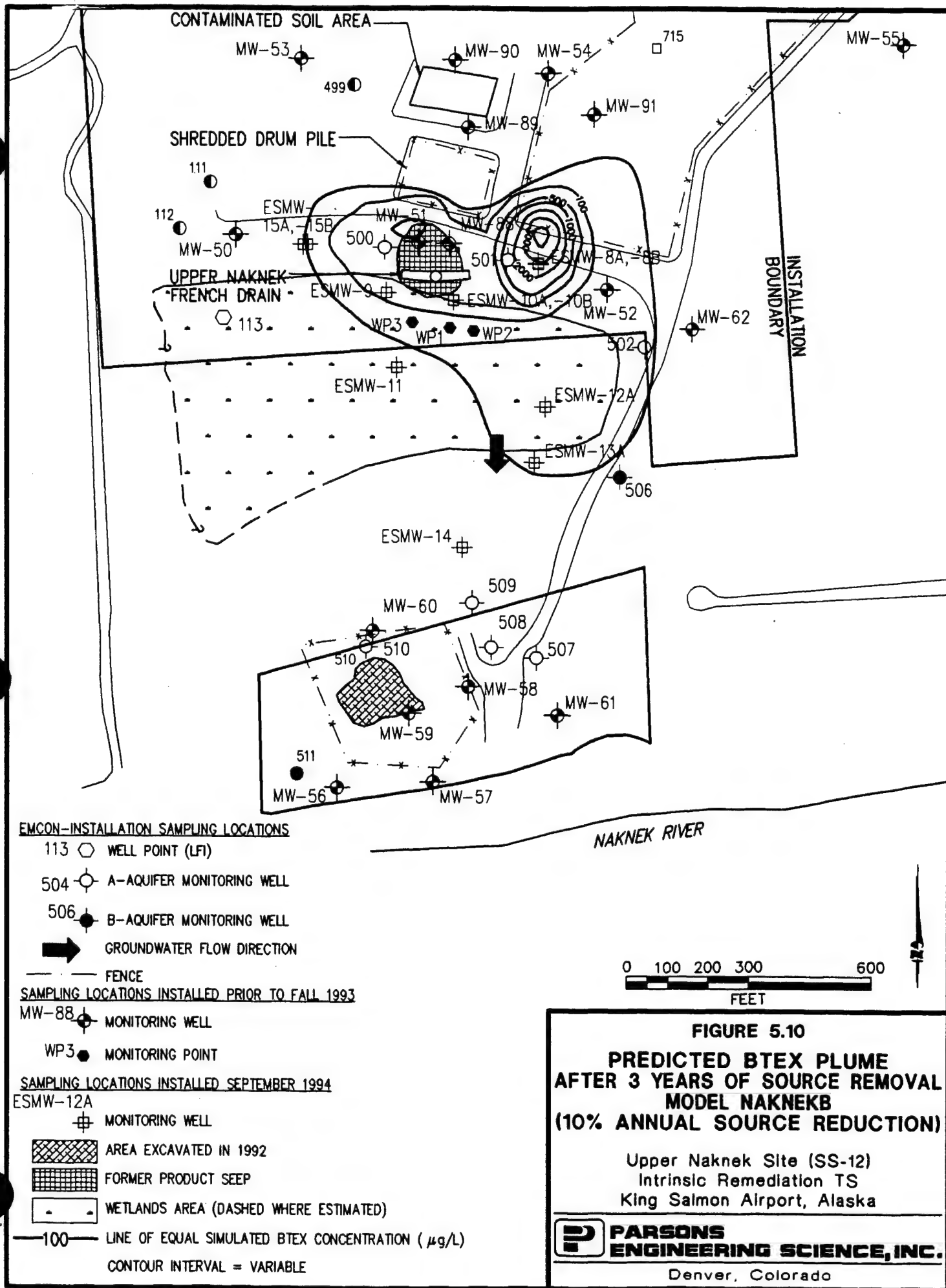
concentrations equal to or exceeding observed site concentrations. It is more likely that as residual-phase hydrocarbons weather and degrade in the source area, the BTEX loading rates will decrease, and the dissolved BTEX concentrations would eventually decrease, resulting in a shrinking plume.

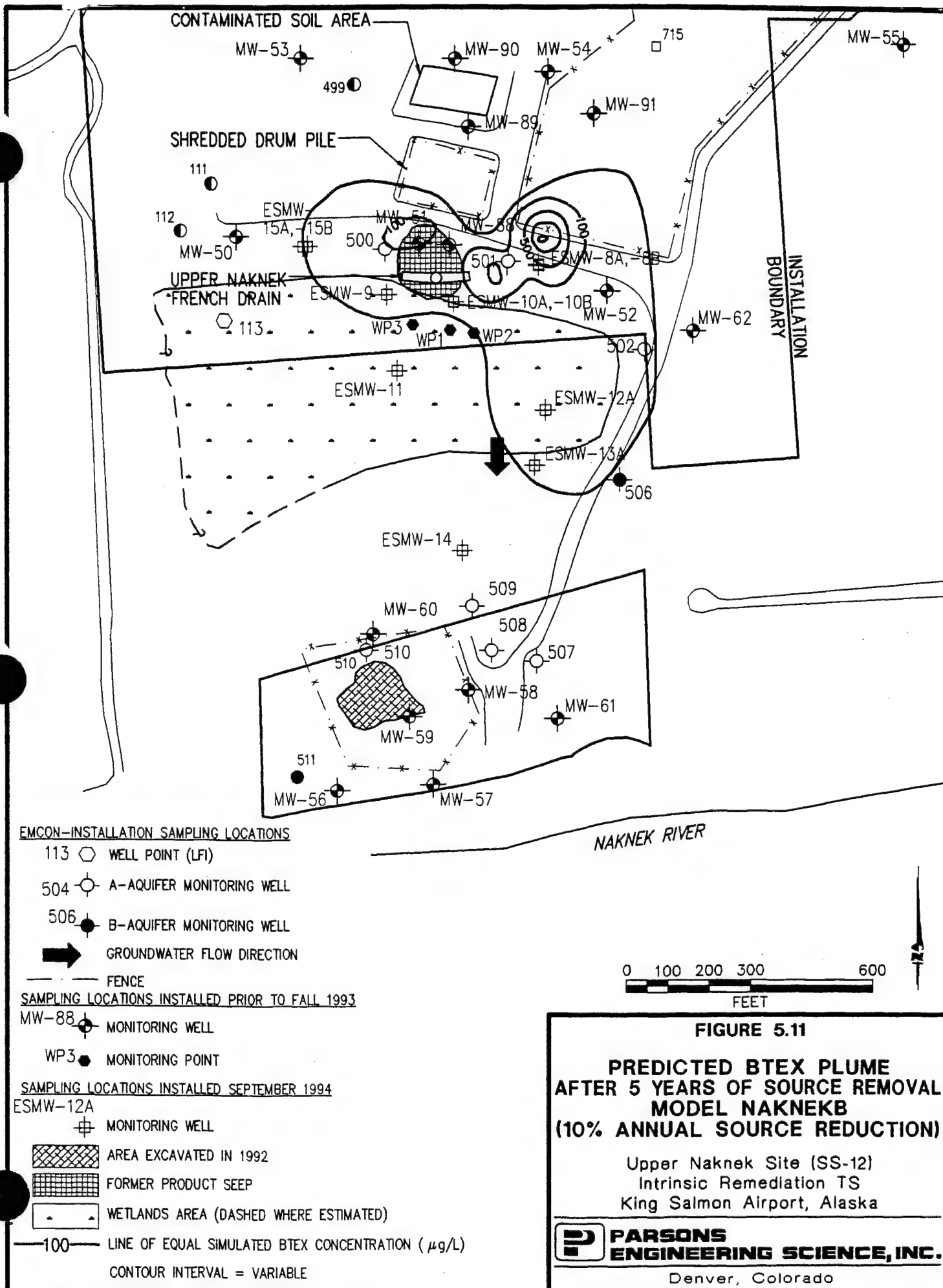
5.6.2 Source Reduction (Model Naknek B)

Several observations were used to design model NaknekB, which simulated a gradual reduction in the contaminant source. Significant free product does not appear to be present at the Upper Naknek Site, although petroleum product seepage (seen as sheens in wetland waters) occurs in the wetland and approximately 0.2 inches of free product was observed in monitoring well 500 in September 1994. In the event that significant LNAPL was present, a french drain installed by SAIC (1993c) would capture the LNAPL. The absence of significant soil contamination at the site suggests that the contaminant source is no longer releasing significant concentrations of hydrocarbons. No noticeable hydrocarbon contamination was observed in the french drain area in September 1994. Site groundwater contamination due to BTEX loading from mobile or residual LNAPL is predicted to decrease through recovery in the french drain, weathering, or other engineered solution (i.e., bioventing). Model NaknekB assumes that these processes reduce contamination at a rate of 10 percent per year for 5 years, at which time the contaminant loading rates would be 50 percent of the original calibrated rates. Model NaknekB predictions would not be applicable if there were new releases from existing USTs and pipelines.

It is important to note that under optimum conditions in coarse-grained soils, a 30 to 50 percent recovery of the spilled fuel is considered excellent. Much of the remaining 50 to 70 percent of the fuel is more tightly occluded and bound in the micropore structure of the soil. *In situ* treatment of this residual fuel could be accomplished using either soil vapor extraction or bioventing technologies. These technologies would potentially be successful in the Upper Naknek area because of the porosity and homogeneity of the soil, but could be influenced by the colder temperatures of the region.

Through 10 percent annual reductions of contaminant source, the magnitude and extent of the hydrocarbon plume decreased. Figure 5.10 shows the plume 3 years after implementing source removal, after a 30 percent reduction in the contaminant source. The reduction in contaminant mass began after the plume stabilized [year four of the original model (NaknekA)]. Figure 5.10 indicates the plume configuration after a 30 percent reduction in contaminant loading is achieved. The resulting BTEX plume is similar in size to the original plume, but the maximum plume concentrations are nearly 2,000 µg/L lower. After a 50 percent reduction of the contaminant source (Figure 5.11), the maximum plume concentration is 1,400 µg/L and the plume area is noticeably smaller. Although the total contaminant mass is significantly reduced after a 50 percent reduction of the original loading rates, the downgradient extent of the plume is the same as that of the 1994 plume. An extra model run revealed that natural attenuation mechanisms will not completely remove the dissolved plume until loading rates are reduced to 30 percent of the calibrated model values.





5.7 CONCLUSIONS AND DISCUSSION

The results of two Bioplume II model scenarios for the Upper Naknek Site suggest that the dissolved BTEX plume front is not likely to migrate more than 150 feet downgradient past the observed September 1994 position. The first scenario, model NaknekA, assumed that conditions that produced the calibrated model would remain constant (i.e., there would be no reduction in source loading). The second scenario, model NaknekB, assumed that due to a combination of weathering, LNAPL recovery in the french drain, and/or installation of a bioventing unit, the source loading rates would gradually decrease to 50 percent of the calibrated rates over a period of 5 years. Model NaknekA results suggest that after 4 years, the modeled plume BTEX plume reached its maximum extent, approximately 150 feet downgradient from the observed plume in 1994. Model NaknekB results suggest that after source reduction, the BTEX plume configuration will remain the same except that maximum concentrations will decrease. The BTEX plume is predicted to completely disappear when source loading rates reach approximately 30 percent of their present rate.

Because the source is assumed to continue to release dissolved BTEX into the groundwater, both scenarios indicate that the plume will not dissipate unless substantial source removal occurs naturally (i.e., through weathering) or through an engineered solution (e.g., a bioventing system). Accurately quantifying and modeling the results of these processes would be impractical and would require very extensive definition of source area characteristics. However, examination of NaknekA results suggest that the plume may recede, instead of grow, because the majority of the modeled parameters were conservative in nature. The conservative nature of model NaknekA input also suggests that the model may overestimate plume travel distances.

In both cases, model simulations are conservative for several reasons, including:

- 1) Aerobic respiration, iron reduction and methanogenesis are occurring; however, only DO was considered as an electron acceptor during model simulations.
- 2) The stoichiometry used to determine the ratio between DO and total BTEX assumed that no microbial cell mass was produced during the reaction. As discussed in Section 4.3.2.1, this approach may be too conservative by a factor of three.
- 3) A low coefficient of retardation for benzene (1.5) was used for all the BTEX compounds in the model simulations. This value was based on an average soil TOC of 0.1 percent, which may be low based on the measured TOCs that ranged from 0.024 to 1.878 percent. The use of a conservative retardation coefficient tended to increase source concentrations (as discussed in Section 5.5) and contaminant mobility, increasing the conservative nature of the models.
- 4) A relatively low porosity value of 0.25 was used for the model. Porosities characteristic of the soils present at the site typically range from 0.25 to 0.50 (Freeze and Cherry, 1979). Lower porosity increases the simulated groundwater velocity and contaminant velocity.

The conservative assumptions used for models NaknekA and NaknekB increase the likelihood that the models may actually overestimate the extent of the contamination or the life expectancy of the plume. Contaminant migration rates, under the influence of advection, dispersion, and sorption, are expected to be at least 170 feet per year. At this velocity, groundwater contamination should have traveled much farther than indicated by groundwater monitoring well sampling results or model predictions, especially if the spills originally occurred in the mid-1980s. This indicates that biodegradation is significantly limiting BTEX migration. Hence, the rapid stabilization of the model, taking into consideration the conservative estimates used, is plausible and the observed BTEX plume is likely a stable plume.

SECTION 6

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

This section presents the development and comparative analysis of two groundwater remedial alternatives for the Upper Naknek Site at KSA. The intent of this evaluation is to determine if intrinsic remediation is an appropriate and cost-effective remedial technology to consider when developing final remedial strategies for the Upper Naknek Site, especially when combined with other innovative and conventional remedial technologies.

Section 6.1 presents the evaluation criteria used to evaluate the groundwater remedial alternatives. Section 6.2 discusses the development of remedial alternatives considered as part of this demonstration project. Section 6.3 provides a brief description of each of these remedial alternatives. Section 6.4 provides a more detailed analysis of the remedial alternatives using the defined remedial alternative evaluation criteria. The results of this evaluation process are summarized in Section 6.5.

6.1 REMEDIAL ALTERNATIVE EVALUATION CRITERIA

The evaluation criteria used to identify the appropriate remedial alternative for shallow groundwater contamination at the Upper Naknek Site were adapted from those recommended by the EPA (1988) for selecting remedies for Superfund sites (OSWER Directive 9355.3-01). These criteria include (1) long-term effectiveness and permanence, (2) technical and administrative implementability, and (3) relative cost. The following sections briefly describe the scope and purpose of each evaluation criterion. This report focuses on the potential use of intrinsic remediation and source reduction technologies to reduce BTEX concentrations in shallow groundwater to concentrations that meet regulatory action levels.

6.1.1 Long-Term Effectiveness and Permanence

Each remedial technology or remedial alternative (which can be a combination of remedial technologies such as intrinsic remediation and institutional controls) was analyzed to determine how effectively it will minimize groundwater plume expansion so that groundwater quality standards can be achieved at a downgradient POC. The expected technical effectiveness based on case histories from other sites with similar conditions is also evaluated. The ability to minimize potential impacts on surrounding facilities and operations is considered. Also, the ability of each remedial alternative to protect both current and potential future receptors from potential threats associated with site-related contamination in shallow groundwater, based on regulatory action levels for BTEX, is qualitatively assessed by conservatively estimating if a potential exposure pathway involving groundwater could be completed, either now or in the future. This

evaluation criterion also included permanence and the ability to reduce contaminant mass and volume. Time to implementation and time until protection is achieved are described. Long-term reliability for providing continued protection, including an assessment of potential for failure of the technology and the potential threats resulting from such a failure, is also evaluated.

6.1.2 Implementability

The technical implementation of each remedial technology or remedial alternative was evaluated in terms of technical feasibility and availability. Potential shortcomings and difficulties in construction, operations, and monitoring are presented and weighed against perceived benefits. Requirements for any post-implementation site controls such as LTM and land use restrictions are described. Details on administrative feasibility in terms of the likelihood of public acceptance and the ability to obtain necessary approvals are discussed.

6.1.3 Cost

The total cost (present worth) of each remedial alternative was estimated for relative comparison. An estimate of capital costs, and operations and post-implementation costs for site monitoring and controls is included. An annual inflation factor of five percent was assumed in present worth calculations.

6.2 FACTORS INFLUENCING ALTERNATIVES DEVELOPMENT

Several factors were considered during the identification and screening of remedial technologies for addressing shallow groundwater contamination at the Upper Naknek Site. Factors considered included the objectives of the natural attenuation demonstration program; site contaminant, groundwater, and soil properties; present and future land use; and potential exposure pathways. The following section briefly describes each of these factors and how they were used to narrow the list of potentially applicable remedial technologies to the final remedial alternatives considered for the Upper Naknek Site.

6.2.1 Program Objectives

The intent of the intrinsic remediation demonstration program sponsored by AFCEE is to develop a systematic process for scientifically investigating and documenting naturally occurring subsurface attenuation processes that can be factored into overall site remediation plans. The objective of this program and the specific Upper Naknek Site study is to provide solid evidence of intrinsic remediation of dissolved fuel hydrocarbons so that this information can be used to develop an effective groundwater remediation strategy. A secondary goal of this multi-site initiative is to provide a series of regional case studies that demonstrate that natural processes of contaminant degradation can often reduce contaminant concentrations in groundwater to below acceptable cleanup standards before completion of potential exposure pathways to receptors.

Because the objective of this program is to study natural processes in the saturated zone rather than all contaminated media (vadose zone soil, soil gas, etc.), technologies have been evaluated primarily on their potential impact on shallow groundwater and phreatic soils. However, technologies that can reduce vadose zone contamination and

partitioning of contaminants into groundwater have also been evaluated. Source removal technologies evaluated in this section will also reduce soil and soil gas contamination, but it is important to emphasize that the remedial alternatives developed in this document are not intended to remediate all contaminated media. Additional program objectives set forth by AFCEE include cost effectiveness and minimization of waste. Technologies that may meet these criteria include institutional controls, soil vapor extraction, bioventing, biosparging, groundwater pump and treat, and intrinsic remediation. Soil excavation, slurry walls, sheet piling, carbon adsorption, *ex situ* biological or chemical treatment, and onsite/offsite disposal are not attractive technology candidates for this site.

6.2.2 Contaminant Properties

The site-related contaminants considered as part of this demonstration at the Upper Naknek Site are the BTEX compounds. The source of this contamination is weathered petroleum (i.e., JP-4 fuel) present as residual contamination in capillary fringe and saturated soil adjacent to the southern borders of the shredded drum pile operation and the fenced fuel storage yard of the Upper Naknek Site. The physiochemical characteristics of JP-4 and the individual BTEX compounds will greatly influence the effectiveness and selection of a remedial technology.

Petroleum hydrocarbon mixtures, such as JP-4, are composed of over 300 compounds with different physiochemical characteristics. JP-4 is classified as an LNAPL with a liquid density of 0.75 gram per cubic centimeter (g/cc) at 20°C (Smith *et al.*, 1981). Many compounds in JP-4 sorb very well to soil and are concentrated in the capillary fringe because the mixture is less dense than water. JP-4 is slightly soluble in water, each with a maximum solubility of approximately 300 mg/L. JP-4 is also a primary substrates for biological metabolism. Simultaneous biodegradation of aliphatic, aromatic, and alicyclic hydrocarbons has been observed. In fact, mineralization rates of hydrocarbons in mixtures, such as JP-4 or gasoline, may be faster than mineralization of the individual constituents as a result of cometabolic pathways (Jamison *et al.*, 1975; Perry, 1984).

The BTEX compounds are generally volatile, highly soluble in water, and adsorb less strongly to soil than other hydrocarbons in a petroleum mixture. These characteristics allow the BTEX compounds to leach more rapidly from contaminated soil into groundwater, and to migrate as dissolved contamination (Lyman *et al.*, 1992). All of the BTEX compounds are highly amenable to *in situ* degradation by both biotic and abiotic mechanisms. Maximum dissolved BTEX concentration that can result from the equilibrium partitioning of BTEX compounds from JP-4 into groundwater is approximately 30 mg/L (30,000 µg/L) as estimated by Smith *et al.* (1981).

Benzene is very volatile, with a vapor pressure of 76 millimeters of mercury (mm Hg) at 20°C and a Henry's Law Constant of approximately 0.0054 atmosphere-cubic meters per mole (atm-m³/mole) at 25°C (Hine and Mookerjee, 1975; Jury *et al.*, 1984). The solubility of pure benzene in water at 20°C has been reported to be 1,780 mg/L (Verschuere, 1983). Benzene is normally biodegraded to carbon dioxide, with catechol as a short-lived intermediate (Hopper, 1978; Ribbons and Eaton, 1992).

Toluene is also volatile, with a vapor pressure of 22 mm Hg at 20°C and a Henry's Law Constant of about 0.0067 atm-m³/mole at 25°C (Pankow and Rosen, 1988; Hine and Mookerjee, 1975). Toluene sorbs more readily to soil media relative to benzene, but still

is very mobile. The solubility of pure toluene in water at 20°C is approximately 515 mg/L (Verschueren, 1983). Toluene has been shown to degrade to pyruvate, caetaldehyde, and completely to carbon dioxide via the intermediate catechol (Hopper, 1978; Wilson *et al.*, 1986; Ribbons and Eaton, 1992).

Ethylbenzene has a vapor pressure of 7 mm Hg at 20°C and a Henry's Law Constant of 0.0066 atm-m³/mole (Pankow and Rosen, 1988; Valsaraj, 1988). Ethylbenzene sorbs more strongly to soils than benzene but less strongly than toluene (Abdul *et al.*, 1987). Pure ethylbenzene is also less soluble than benzene and toluene in water at 152 mg/L at 20°C (Verschueren, 1983; Miller *et al.*, 1985). Ethylbenzene ultimately degrades to carbon dioxide via its intermediate 3-ethylcatechol (Hopper, 1978; Ribbons and Eaton, 1992).

The three isomers of xylene have vapor pressures ranging from 7 to 9 mm Hg at 20°C and Henry's Law Constants of between 0.005 and 0.007 atm-m³/mole at 25°C (Mackay and Wolkoff, 1973; Hine and Mookerjee, 1975; Pankow and Rosen, 1988). Of all of the BTEX compounds, xylenes sorb most strongly to soil, but still can leach from soil into the groundwater (Abdul *et al.*, 1987). Pure xylenes have water solubilities of 152 to 160 mg/L at 20°C (Bohon and Claussen, 1951; Mackay and Shiu, 1981; Isnard and Lambert, 1988). Xylenes can degrade to carbon dioxide via pyruvate carbonyl intermediates (Hopper, 1978; Ribbons and Eaton, 1992).

On the basis of these physiochemical characteristics, intrinsic remediation, soil vapor extraction, bioventing, biosparging, and groundwater extraction and air stripping technologies could all be effective at collecting, destroying, and/or treating BTEX contaminants at the Upper Naknek Site.

6.2.3 Site-Specific Conditions

Two general categories of site-specific characteristics were considered when identifying remedial technologies for comparative evaluation as part of this demonstration project. The first category was physical characteristics such as groundwater depth, gradient, flow direction, and soil type, which influence the types of remedial technologies most appropriate for the site. The second category involved assumptions about future land use and potential exposure pathways. Each of these site-specific characteristics has influenced the selection of remedial alternatives included in the comparative evaluation.

6.2.3.1 Groundwater and Soil Characteristics

Site geology and hydrogeology will have a profound effect on the transport of contaminants and the effectiveness and scope of required remedial technologies at a given site. Hydraulic conductivity is perhaps the most important aquifer parameter governing groundwater flow and contaminant transport in the subsurface. The velocity of the groundwater and dissolved contamination is directly related to the hydraulic conductivity of the saturated zone, which influences the fate and transport of contaminants. Hydraulic conductivity estimates for the Upper Naknek Site ranged from 0.01986 to 0.02998 ft/min, with an average of 0.02239 ft/min, based on slug tests performed at two well locations (Section 3.3.2.2). These hydraulic conductivity values are reasonable for the types of sandy soil encountered in the area, and are similar to values calculated in a facility-wide

hydraulic conductivity survey performed by CH₂M Hill (1990). Migration of the groundwater plume in the conductive soils at the site has increased the areal extent of contamination (i.e., the plume has expanded) downgradient and crossgradient relative to the contaminant sources.

Hydraulic conductivity affects plume expansion and migration, and will also impact the effectiveness of other remedial technologies, such as groundwater extraction and intrinsic remediation. For example, it would be less expensive and time-consuming to capture and treat the contaminant plume using a network of extraction wells in areas of high hydraulic conductivity than in areas of low conductivity. Generally, most areas at the Upper Naknek Site are in zones of high hydraulic conductivity. Lower hydraulic conductivities may be encountered in the wetland areas beginning at the edge of monitoring well ESMW-10, because of the occasional presence of frozen soil and/or the high organic content of the upper wetland soils. Migration of contaminants within the subsurface away from the sources inherently increases the effectiveness of natural biodegradation processes by: 1) distributing the contaminant mass into areas enriched with electron acceptors (described below), and; 2) diluting contaminants in the saturated zone to lower concentrations through mechanical and molecular dispersion.

In addition to abiotic losses of contamination through migration, dilution, and sorption, biodegradation of contamination is the next most significant natural mechanism affecting contaminant fate and transport. For biological degradation of hydrocarbons to occur, the aquifer must also provide an adequate and available carbon or energy source (e.g., the contamination), electron acceptors, essential nutrients, proper ranges of pH, temperature, and redox potential. Data collected as part of the field work phase of this TS, and described in Sections 3 and 4 of this document, indicate that the Upper Naknek Site groundwater contains adequate and available carbon/energy sources and electron acceptors to support measurable biodegradation of fuel hydrocarbon contamination by indigenous microorganisms. DO, ferric iron, and carbon dioxide (which is utilized during methanogenesis) represent electron acceptors currently utilized at the site for the biodegradation of BTEX compounds. Nitrate and sulfate are also present at the site as electron acceptors, but apparently are not being utilized for BTEX biodegradation (Section 4). Further, because fuel-hydrocarbon-degrading microorganisms have been known to thrive under a wide range of temperature and pH conditions (Chapelle, 1993), the physical and chemical conditions of the groundwater and phreatic soil at the Upper Naknek Site are not likely to prevent microorganism growth.

Fuel hydrocarbon-degrading microorganisms are ubiquitous, and as many as 28 hydrocarbon-degrading isolates (bacteria and fungi) have been discovered in different soil environments (Davies and Westlake, 1979; Jones and Eddington, 1968). Indigenous microorganisms have a distinct advantage over microorganisms injected into the subsurface to enhance biodegradation because indigenous microorganisms are well adapted to the physical and chemical conditions of the subsurface in which they reside (Goldstein *et al.*, 1985). Microbe addition was not considered a viable remedial technology for the Upper Naknek Site.

Contaminant recovery may also be maximized when contaminants are not significantly sorbed to and retarded by phreatic soil. The Upper Naknek Site soils have moderate to high TOC contents (up to 1.9 percent), as a result of fuel contamination or high vegetative organic carbon content. The degree of contaminant sorption is governed

by the mass of TOC in the soil (which is higher in the vicinity of the wetland) and can limit the mobility of contaminants in groundwater if extraction technologies, such as pump and treat, are used.

6.2.3.2 Potential Exposure Pathways

A pathways analysis identifies the potential human and ecological receptors that could come into contact with site-related contamination, and the pathways through which these receptors might be exposed. To have a completed exposure pathway, there must be a source of contamination, a potential mechanism(s) of release, a pathway of transport to an exposure point, an exposure point, and a receptor. If any of these elements do not exist, the exposure pathway is considered incomplete, and receptors will not come into contact with site-related contamination. If a completed exposure pathway exists (e.g., surface water contact), potential long-term remedial options may still be sufficient to maintain exposure concentrations below regulatory action levels. Establishing site-specific risk-based cleanup levels is beyond the scope of this TS.

Assumptions about current and future land uses at a site form the basis for identifying potential receptors, potential exposure pathways, reasonable exposure scenarios, and appropriate remediation goals. EPA (1991a) advises that the land use associated with the highest (most conservative) potential level of exposure and risk that can reasonably be expected to occur should be used to guide the identification of potential exposure pathways and to determine the level to which the site must be remediated.

Man-made features associated with the source area for the eastern plume (near ESMW-8) consist of USTs, pump houses, and transfer lines. Features associated with the western source (near MW-51) consist of a shredded drum pile and land suspected to have once contained old USTs (according to base personnel). The area immediately north of the site is undeveloped, except for gravel roads, and is separated from the main east/west road connecting King Salmon with the town of Naknek by a few hundred feet of sparsely vegetated, arctic forest. East and west of the source areas, and within Air Force property boundaries (Figure 1.3), are stretches of cleared land fringed by forested areas. The area immediately south of the site includes a few thousand square feet of wetland terrain (Figure 1.4), which recedes into a patch of arctic forest at the southern edge (near ESMW-13). Current information suggests that this wetland has not been evaluated in terms of the US Army Corps of Engineers (USACE) jurisdictional criteria. Other fuel storage facilities are located farther downgradient at the lower Naknek Site. Residential developments are present at least 1,500 feet southeast and southwest of the source areas, but they are not directly downgradient of contamination. Ultimately, groundwater from the shallow aquifer discharges into the Naknek River, which is 2,000 feet south of the site.

The groundwater plume originating from the Upper Naknek Site is migrating to the south, and has impacted groundwater underlying the area extending from the vicinity of the tanks (or former tanks in the source area) to approximately 500 feet downgradient. Site data suggest the front of the hydrocarbon plume has migrated beneath the wetland (Figures 4.2) and may be discharging to the surface at the groundwater/surface water interface. Considering the current plume extent and the future migration potential, three potential receptor exposure pathways via different media exist at the site and include: 1) exposure of potential (future) downgradient well users, or receptors using the Naknek

River, through continued, downgradient advective-dispersive transport of the contaminant plume; 2) exposure through contact with surface water into which contaminated groundwater discharges (e.g., in the topographically low areas defined by the wetland); and, 3) exposure through ingestion of B-Aquifer well waters affected by downward migration of contaminants through the A-aquitard. Under reasonable current land use assumptions, potential receptors that could be exposed to these media include site workers and recreators (adjacent residents occasionally pass through the area), potential downgradient well users, and/or ecological receptors, including wetland vegetation and animal species.

The exposure pathway to downgradient receptors in the shallow aquifer is considered incomplete. Groundwater from the surface aquifer near the site is not used to meet any potable or nonpotable water demands. KSA water demands are met by supply wells screened in a deeper confined aquifer. No private wells are known to exist directly downgradient of the groundwater contamination. Model results predict that existing contamination will not migrate more than 150 feet downgradient of the observed plume front. Natural attenuation mechanisms prevent completion of an exposure pathway to downgradient A-Aquifer users or the Naknek River. Long-term verification of this observation is dependent on a LTM plan, as discussed in Section 6.3.1.

The two other potential exposure routes must also be considered with the same criteria as the shallow groundwater contamination. Groundwater discharges to the wetland just below the bluff of the Upper Naknek and near monitoring well ESMW-10. This wetland extends for an additional 300 feet south before receding into patches of forest. Because groundwater discharges to the wetland, an exposure pathway exists from contaminated groundwater to wetland surface waters. Preferential flow pathways for surface waters from the wetland (e.g., tributaries or streams) do not exist. Ecological receptors may be exposed to contaminants in wetland surface water. Human contact with wetland water is considered extremely unlikely, given the location of the site. Surface water in the wetland recharges into the aquifer at downgradient locations, and eventually reaches the Naknek River. Potential BTEX concentrations in wetland waters are believed to be low, considering the low concentration of total BTEX detected in the aquifer below the wetland (<200 µg/L) and because of potential loss of BTEX contamination to mechanisms such as volatilization, dilution, photooxidation, and continued biodegradation.

Surface water samples from the wetland are not available to document potential BTEX contamination in the waters. However, four shallow wells were placed in the wetland and screened across the water table during September 1994 site investigation activities (ESMW-9A, ESMW-10A, ESMW-11A, and ESMW-12A) (Section 2), which augmented the sampling network of three shallow monitoring wells installed during a previous study (WP1, WP2, and WP3). All these monitoring wells were screened across or near the water table (at or near the land surface). The maximum total BTEX concentration in any of these wells was 136 µg/L at ESMW-10A (Table 4.3). Although the wells were intended for sampling of groundwater in the shallow aquifer, the proximity of the screened intervals to the surface waters of the wetland allows data from these wells to be used as a conservative estimate of surface water contamination in the area (potential surface water contamination due to groundwater discharge would be subjected to increased abiotic losses such as volatilization, photooxidation, and dilution of compounds at the surface). A surface soil sample collected at ESMW-10 at 0 to 2 feet bgs also was

analyzed for BTEX compounds. Total BTEX were measured at 1,600 µg/kg in this sample (Table 4.1).

The groundwater and soil BTEX results for sampling locations in or near the wetland suggest that exposure pathways are complete for ecological receptors that may contact wetland surface water or sediment. However, eventual discharge of contaminated shallow groundwater into the Naknek River is not anticipated based on model results. However, if concentrations of contaminants reached the Naknek River, they would likely be quickly diluted to concentrations lower than those found in the wetlands, and therefore would pose little threat to receptors.

The final potential exposure pathway at the Upper Naknek Site could result from migration of BTEX from the A-Aquifer to the B-Aquifer. This was considered because low concentrations of toluene were found at monitoring well 506, reportedly screened in the B-Aquifer. This monitoring well had recorded toluene concentrations at 3.0 and 6.6 µg/L in 1993 and 1994, respectively. Both these values are well below the federal drinking water maximum contaminant level (MCL) of 1,000 µg/L for toluene. Monitoring well 506 is located directly downgradient of the eastern source of the hydrocarbon plume at the site. Potential downgradient receptors are considered to be B-Aquifer well users, although no known private wells in the B-Aquifer are known to exist between monitoring well 506 and the Naknek River. The general flow pattern of the B-Aquifer is expected to be similar to the A-Aquifer in the Upper Naknek area, with groundwater discharging to the Naknek River. Thus, any potential lower aquifer contamination would be expected to follow a similar migration route as the shallow aquifer contamination. The southern bank of the Naknek River is not developed.

Although this report focuses on contamination in the groundwater, possible health threat from incidental soil contact was briefly considered. It is unlikely that potential receptors could be exposed to site-related contamination in phreatic soils unless this material is removed during future construction excavations or remedial activities. Soil data do not indicate any widespread areas of soil BTEX contamination, and the potential for health risk from soil contact appears insignificant. Exposure pathways involving other environmental media such as shallow soils and soil gas in the source area were not considered as part of this project, but should be considered in overall site remediation decisions.

Assumptions about hypothetical future land uses must also be made to ensure that the remedial technology or alternative considered for shallow groundwater at the site is adequate and sufficient to provide long-term protection. No future changes in land use in the area of potential site influence are anticipated, so a military/industrial land use assumption is most appropriate. As previously mentioned, potential current and future receptors include ecological receptors and human receptors such as worker populations, potential downgradient well users, or occasional recreators. Human contact with surface waters is considered extremely unlikely, especially in the wetland area. In summary, the use of the intrinsic remediation technology at this site will require that the source area be maintained as industrial property and that restrictions on shallow groundwater use be enforced in areas downgradient of the Upper Naknek Site until natural attenuation reduces contaminants to levels that pose no risk. If additional source removal technologies such as soil vapor extraction, bioventing, biosparging, or groundwater pump and treat are implemented, they will have some impact on the short- and long-term land

use options and will require some level of institutional control and worker protection during construction and operation.

6.2.3.3 Remediation Goals for Shallow Groundwater

Model results suggest that BTEX compounds in the A-Aquifer are not likely to migrate more than 150 feet downgradient of the observed plume front. Therefore, an area approximately 100 feet beyond the maximum modeled plume boundary (Figure 5.9) has been identified as the POC for groundwater remedial activities because this appears to be the maximum likely extent of future contaminant migration. B-Aquifer POC wells should also be installed at the same locations. The POC locations are suitable for monitoring and for demonstrating compliance with protective groundwater quality standards, such as promulgated groundwater MCLs. In addition, the wells would be outside of the wetland, allowing drilling rig access.

This remedial strategy assumes that compliance with promulgated, single-point remediation goals is not necessary if site-related contamination does not pose a threat to human health or the environment in the A- and B-Aquifers. Thus, the magnitude of required remediation in areas that can and will be placed under institutional control is different from the remediation that is required in areas that may be available for unrestricted use. The primary RAO for shallow groundwater within and downgradient of the Upper Naknek Site is limitation of plume expansion to prevent increased or potential exposure to downgradient receptors to concentrations of BTEX in groundwater. This means that viable remedial alternatives must be able to achieve concentrations that minimize plume migration and/or expansion in both aquifers. The RAO for shallow and deep groundwater at the POC is attainment of federal drinking water MCLs for each of the BTEX compounds as listed in Table 6.1.

TABLE 6.1
POINT-OF-COMPLIANCE REMEDIATION GOALS
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

Compound	Federal MCL (µg/L)	POC Remediation Goal (µg/L)
Benzene	5	<5
Toluene	1,000	<1,000
Ethylbenzene	700	<700
Total Xylenes	10,000	<10,000

In summary, it is likely that BTEX contamination in groundwater in both aquifers is likely to remain at current concentrations or below, but that pathways to potential receptors are not likely to be completed. Restricted use of A-Aquifer or B-Aquifer

groundwater should be enforced by institutional controls within the plume area that covers the Upper Naknek Site source areas, the wetland area, and approximately 250 feet downgradient of the 1994 plume front. Thus, institutional controls are likely to be a necessary component of any groundwater remediation strategy for this site. The required duration of these institutional controls may vary depending on the effectiveness of the selected remedial technology at reducing contaminant mass and concentration in the groundwater.

6.2.3.4 Remediation Goals for Wetland Surface Water and Sediments

Surface water and sediment samples from the wetland have not been evaluated. However, near-surface groundwater and soil BTEX results suggest that contaminants from the Upper Naknek Site have migrated into wetland media to which ecological receptors may be exposed. It is highly likely that intrinsic remediation of hydrocarbons will attenuate BTEX contamination to very low concentrations as explained in Section 6.3.1. Surface water and sediment sampling should be performed as part of the remedial alternative to verify that intrinsic remediation is reducing potential contamination in these media to below state criteria for surface waters and sediments. Currently, there are no enforceable Alaskan sediment quality criteria. The RAO for wetland surface waters is attainment of Alaskan surface water quality criteria. Current Alaskan water quality standards under section 10 AAC 70.020 (1989) for the protection of fresh water for the growth and propagation of fish, shellfish, other aquatic life, and wildlife specify protective limits of 15 µg/L for total hydrocarbons and 10 µg/L for total aromatic hydrocarbons in the water column. New criteria to be published in April 1995 may impose different requirements to both surface waters and sediments. Attainment of these established limits should then be monitored through annual surface water and sediment sampling, as outlined in Section 7. Surface waters and sediments should also be sampled in uncontaminated areas for total hydrocarbons to ensure that potential, background interferences (e.g., organic acids, humates, and suspended materials) are not increasing potential hydrocarbon concentrations.

In the event that contaminant concentrations exceed Alaskan surface water and sediment quality standards, implementation of additional remedial alternatives and/or a reevaluation of the RAOs will be required. Instead of using an engineered remedial solution to mitigate potential wetland contamination, remedial action objectives for the wetland could conceivably be altered to meet target risk values defined by a site-specific, predictive risk assessment (a remedial alternative considered in Section 6.3.1). It is possible that potential contaminant concentrations would not reach levels that pose risks to ecological receptors. Attainment of target risk levels instead of Alaskan water quality standards for wetland RAOs would be subject to regulatory approval.

6.2.4 Summary of Remedial Technology Screening

Several remedial technologies have been identified and screened for use in treating the shallow groundwater at the Upper Naknek Site. Table 6.2 identifies the initial remedial technologies considered as part of this demonstration and those retained for detailed comparative analysis. Screening was conducted systematically by considering the program objectives of the AFCEE intrinsic remediation demonstration, physiochemical properties of the BTEX compounds, and other site-specific characteristics such as hydrogeology, land use assumptions, potential exposure pathways, and appropriate

TABLE 6.2
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER REMEDIATION
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

General Response Action	Technology Type	Process Option	Implementability	Retain
Long-Term Monitoring	Periodic Groundwater Monitoring	Confirmation Wells	Many existing wells are available to confirm the progress of remediation.	Yes
		Point-of-Compliance Wells	Sufficient distance exists between the plume and point-of-compliance to locate several wells.	Yes
Institutional Controls	Groundwater Use Control	Land Use Control/Regulate Well Permits	Plume area is currently within the base boundary and land-use and groundwater use are under base jurisdiction.	Yes
		Seal/Abandon Existing Wells	No production wells are known to exist in the existing or predicted plume area.	No
		Point-of-Use Treatment	No groundwater is extracted from the plume area for any use.	No
		Meetings/Newsletters	Base public relations and environmental management offices have many information avenues to workers and residents.	Yes
Containment of Plume	Hydraulic Controls	Passive Drain Collection	No likely receptors downgradient of site, except for possible ecological receptors in the wetland. Installation could impact surface waters and vegetation of the wetland.	No
		Minimum Pumping/Gradient Control	A line or semicircle of vertical pumping wells could be located along the leading edge of plume to intercept and halt the advance of the plume. No likely receptors downgradient of site, except for possible ecological receptors in the wetland.	No
	Physical Controls	Slurry Walls/Grout Curtains	Requires significant disruption of base operating area. Limited effectiveness.	No
		Sheet Piling	Requires significant disruption of base operating area. Limited effectiveness.	No
	Reactive/Semi-Permeable Barriers	Biologically Active Zones	Natural biodegradation of BTEX compounds can be stimulated by allowing contaminated groundwater to flow through an aquifer zone which has enhanced oxygen and nutrient conditions.	No

TABLE 6.2 (Continued)
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER REMEDIATION
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

General Response Action	Technology Type	Process Option	Implementability	Retain
In Situ Treatment	Biological	Oxygen and Nutrient Enhanced Biodegradation	Differs from biologically active zone in that oxygen and nutrients are injected upgradient of plume and allowed to migrate downgradient. In theory, this method can more rapidly reduce higher BTEX concentrations in and immediately downgradient of the source area. Not proven to be more effective than intrinsic remediation	No
	Chemical/Physical	Intrinsic Remediation	A combination of natural biological, chemical, and physical removal mechanisms which occur to varying degrees on every site. Groundwater sampling at Site the Upper Naknek indicates that this is a major, ongoing remediation process.	Yes
		Air Sparging (Volatilization)	Injection of air into contaminated aquifer creating a mass transfer of BTEX into air bubbles and into vadose zone. Limited radius of influence and short-circuiting are common problems.	No
Aboveground Groundwater Treatment	Groundwater Extraction	Vertical Pumping Wells	Entire groundwater plume is pumped by installing numerous wells with submersible pumps. High cost and major disruption to area.	No
		Downgradient Horizontal Drains	See Passive Drain Collection.	No
	Biological	Bioreactors	High flow rates require excessive retention times and large reactors. BTEX is often volatilized in these systems.	No
	Chemical/Physical	Air Stripping	Cost-effective technology for removing varying concentrations of BTEX at higher flow rates. Potential permitting for air emissions.	No
		Activated Carbon	Cost prohibitive for more concentrated BTEX. Creates a carbon disposal problem.	No
		UV/Ozone Reactors	High flow rates require excessive retention times and large, expensive reactors.	No

TABLE 6.2 (Continued)
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER REMEDIATION
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

General Response Action	Technology Type	Process Option	Implementability	Retain
Aboveground Treatment	Direct Discharge to Industrial Waste Water Treatment Plant (IWTP)	IWTP	Viable option when an IWTP is available and capable of handling BTEX and hydraulic loading.	No
	Discharge to IWTP or Sanitary Sewer	IWTP	Viable option when access to sanitary sewer exists and hydraulic loading is acceptable. Groundwater extraction is unlikely.	No
Treated Groundwater Disposal	Treated Groundwater ReInjection	Sanitary Sewer	Viable option when access to sanitary sewer exists and hydraulic loading is acceptable.	No
		Vertical Injection Wells	Not recommended due to clogging and high maintenance.	No
		Injection Trenches	Requires large trenches and can be subject to injection well permitting.	No
		Storm Drains	Viable option but generally requires NPDES or other discharge permit. Groundwater extraction is unlikely.	No
Source Removal/Soil Remediation	Discharge to Surface Waters	Dual-Pump Systems	Best suited for sites with > 1 foot free product where aboveground groundwater treatment already exists	No
		Skimmer Pumps/Bailers/Wicks	Best suited for sites with < 1 foot free product where groundwater pumping is undesirable.	No
	Free Product Recovery	Total Fluids Pumping	Best suited for sites with thin saturated zones where excessive groundwater will not be pumped.	No
		Bioslurping	Combined vapor extraction, bioventing and free product recovery system has been operated at some sites with limited success.	No
	Excavation/Treatment	Biological Landfarming	Excavation is not feasible at this site due to surface structures and facility use.	No

TABLE 6.2 (Concluded)
INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER REMEDIATION
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

General Response Action	Technology Type	Process Option	Implementability	Retain
	Excavation/ Treatment (cont'd)	Thermal Desorption	Excavation is not feasible at this site due to surface structures and site use.	No
	In Situ Removal of Residual LNAPL	Bioventing	Air injection to stimulate biodegradation of fuel residuals.	Yes
		Soil Vapor Extraction	Vapor extraction has been successfully implemented at other sites.	Yes

remediation goals. All of these factors will influence the technical effectiveness, implementation, and relative cost of technologies for remediating shallow groundwater underlying and migrating from the site. The remedial technologies retained for development and comparative analysis of remedial alternatives include institutional controls, intrinsic remediation, LTM, predictive risk assessment, and residual LNAPL removal.

6.3 BRIEF DESCRIPTION OF REMEDIAL ALTERNATIVES

This section describes how remedial technologies retained from the screening process were combined into two remedial alternatives for the Upper Naknek Site. Sufficient information on each remedial alternative is provided to facilitate a comparative analysis of effectiveness, implementability, and cost in Section 6.4.

6.3.1 Alternative 1 - Intrinsic Remediation, Source Identification, Institutional Controls with Long-Term Monitoring, and Contingent Predictive Risk Assessment

Intrinsic remediation is achieved when naturally occurring attenuation mechanisms bring about a reduction in the total mass of a contaminant in the soil or dissolved in groundwater and surface water. Intrinsic remediation results from the integration of several subsurface attenuation mechanisms that are classified as either destructive or nondestructive. Destructive attenuation mechanisms include biodegradation, abiotic oxidation, and hydrolysis. Nondestructive attenuation mechanisms include sorption, dilution (caused by dispersion and infiltration), and volatilization. In some cases, intrinsic remediation will reduce dissolved contaminant concentrations below numerical concentration goals. Evidence of intrinsic remediation described in Section 4 indicates that these processes are occurring at the Upper Naknek Site and will continue to reduce contaminant mass in the shallow saturated zone.

Results of model NaknekA suggest that the dissolved BTEX plume is close to its maximum, or steady-state, extent. This plume could extend to an estimated maximum of 150 feet downgradient of the plume front indicated by September 1994 data. Results of model NaknekB suggest that gradual source reduction by removal of residual or mobile LNAPL (mobile LNAPL was detected in one well in 1994) and/or natural weathering will further reduce existing groundwater BTEX concentrations and limit plume migration. It is recommended that remedial Alternative 1 be implemented with a source area search to discover if existing contamination is part of an ongoing leak or residual source. This source search would help define the areal and vertical extent of residual contamination at the site, as well as the amount of source contamination and its composition. A Geoprobe® sampling device, which can take numerous samples in a short period of time, is recommended for use in a source area soil survey. Recommended locations for Geoprobe® sampling are described in Section 7.

It is possible that portions of the B-Aquifer have also been contaminated by hydrocarbon contamination, though insufficient data exists to document the actual concentration or extent. This contamination may derived from vertical migration of BTEX contamination from the A-Aquifer through the confining layer (the A-Aquitard). Any contamination in the lower aquifer is unlikely to have originated at an unidentified secondary source, as well 506 (reportedly screened in the B-Aquifer) is downgradient from soil and groundwater contamination on the eastern side of the shallow groundwater

plume. Only toluene was detected in this well and it was orders of magnitude lower than the federally regulated MCL for drinking water of 1,000 µg/L. Since most of the LNAPL contamination is being transported and attenuated in the shallow water, it is reasonable to assume that any contaminant concentrations in the B-Aquifer are much lower.

Contamination in the B-Aquitard is subject to the same natural attenuation mechanisms inhibiting plume migration in surface soils, including biodegradation, sorption, and dilution. The DO concentration at monitoring well 506 was 0.3 mg/L, but upgradient DO concentrations are not known. Furthermore, the general flow pattern of the B-Aquifer is believed to be similar to that of the A-Aquifer in that flow is proceeding south toward the Naknek River. It is recommended that potential contamination in the B-Aquifer be monitored through installation of deep wells at POC locations. It is highly likely that potential B-Aquifer contamination is being limited by natural attenuation processes, and that groundwater quality goals at downgradient POCs will be met.

As sentry points warning of potential plume migration, POC wells should be placed at three locations downgradient of the modeled maximum extent (i.e., slightly more than 250 feet downgradient of the September 1994 plume front, or approximately 600 feet downgradient of either plume source). These POC wells should be nested, with wells screened in both the A-Aquifer and the B-Aquifer. In addition, LTM wells within, upgradient and immediately downgradient of the existing BTEX plume would be used to monitor the effectiveness of intrinsic remediation in the A-Aquifer. All of these LTM wells will be at existing well locations, with the exception of one new proposed LTM well location. LTM wells are further described in Section 7.2.1. Detection of any BTEX constituent in excess of federal MCLs (Table 6.1) at the farthest downgradient LTM wells would be an indication that additional evaluation and modeling would be needed to assess BTEX migration and to determine if additional corrective action would be necessary.

Existing data concerning the wetland suggests that BTEX compounds are present in surface water in the wetland. Although the wetland is considered a sensitive ecological environment, wetlands are also typically very effective at removing various contaminants through natural attenuation mechanisms such as sedimentation, filtration, chemical precipitation, chemical adsorption, microbial interactions, and plant uptake (Meyer, 1985; Reuter *et al.*, 1992; Watson *et al.*, 1989). Wetlands have been documented to remove significant concentrations of toxic organics, such as BTEX, oil, and grease (Meyer, 1985; Phillips *et al.*, 1993; Wolverton, 1987). For example, as much as 89 to 98 percent of the benzene and 98 to 99.9 percent of the toluene introduced into a wetland system was removed (Wolverton, 1987). In addition to the physical and biological mechanisms that occur in wetlands, mechanisms such as volatilization and photooxidation will also reduce contaminant concentrations.

Any petroleum hydrocarbon contamination that may reach wetland should be reduced to concentrations below Alaskan water quality criteria through natural attenuation mechanisms. It is recommended that this prediction be supported through annual sampling of wetland surface water and sediments. Current Alaskan regulations do not have criteria for sediment quality; however, newly promulgated Alaskan surface water and sediment criteria should be released by April 1995. These new criteria should act as the compliance limits for potential petroleum hydrocarbon contamination in the wetland. Suggested sampling locations for surface waters and soils are described in Section 7.

In the event that hydrocarbon contamination in wetland surface water and sediments exceed newly promulgated Alaskan regulations for these media, it is recommended that a predictive risk assessment be performed to quantify the actual hazard to site receptors that may come into contact with site surface water and sediments. The use of the predictive risk assessment is recommended primarily to evaluate possible risks associated with contaminated wetland surface waters because it is possible that potential contaminant concentrations would not be reflective of levels that pose risks to ecological receptors. To illustrate this point, the difference between state standards, federal aquatic life criteria, and representative aquatic life toxic-effect values from toxicological studies are shown in Table 6.3. Furthermore, climate characteristics of the area suggest that the wetland area is frozen for significant lengths of time throughout the year, making the wetland less of an ecological risk to ecological receptors because of fewer anticipated indigenous fish and wildlife species. The objective of this risk assessment would be to support the continued use of the natural attenuation option by demonstrating that completed pathways at the site (i.e., the wetland) pose inconsequential risk to exposed receptors. If the results of a predictive risk assessment indicate that site contaminants pose no significant risk to site receptors, the need for engineered remedial options to augment natural attenuation may be reduced. Attainment of target risk values instead of state standards would be subject to regulatory negotiation.

Alternative 1 would require the use of institutional controls such as land use restrictions and LTM. Land use restrictions may include placing long-term restrictions on soil excavation within the source area and long-term restrictions on groundwater well installations within and downgradient of the plume area. The intent of these restrictions would be to reduce potential receptor exposure to contaminants by legally restricting activities within areas affected by site-related contamination. To be conservative, the results of model NaknekA should be considered in making decisions regarding groundwater monitoring and potential land use restrictions.

Public education on the selected alternative would be developed to inform KSA personnel and residents of the scientific principles underlying source reduction and intrinsic remediation. This education could be accomplished through public meetings, presentations, press releases, and posting of signs where appropriate. Periodic site reviews could also be conducted every year using data collected from the long-term groundwater monitoring program. The purpose of these periodic reviews would be to evaluate the extent of contamination, assess contaminant migration and attenuation through time, document the effectiveness of source removal and institutional controls at the site, and reevaluate the need for additional remedial actions at the site.

6.3.2 Alternative 2 - Residual LNAPL Removal Through Bioventing, Intrinsic Remediation, Source Identification, Institutional Controls with Long-Term Monitoring, and Contingent Predictive Risk Assessment

This alternative is identical to Alternative 1, with the exception that remedial activities would include source removal. Bioventing would be used to introduce oxygen into the unsaturated zone in the vicinity of the suspected source area to increase aerobic biodegradation of the BTEX compounds and to decrease plume expansion resulting from leaching of hydrocarbons from the unsaturated zone. Bioventing would be accomplished at this site by injecting air throughout the contaminated soil profile to oxygenate unsaturated soils.

TABLE 6.3
AVAILABLE STANDARDS, CRITERIA, AND GUIDELINES FOR THE
PROTECTION OF AQUATIC LIFE AND WILDLIFE
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

Contaminant	Unit	Maximum Concentrations at the Groundwater/Surface Water Interface of the Wetland	State Water Quality Standard ^{a/}	EPA Water Quality Criteria ^{b/}	Toxicity Guidelines ^{c/}
Benzene	µg/L ^{d/}	14.0	-	5,300 ^{e/}	-
Ethylbenzene	µg/L	20.7	-	32,000 ^{e/}	-
Toluene	µg/L	1.0	-	17,500 ^{e/}	60,000 ^{f/}
m-Xylene	µg/L	34.7	-	-	10,000 ^{f/}
o-Xylene	µg/L	33.1	-	-	10,000 ^{f/}
p-Xylene	µg/L	32.6	-	-	10,000 ^{f/}
Total BTEX	µg/L	136	10	-	-
TPH	mg/L ^{g/}		0.015	-	-

^{a/} Alaska Water Quality Standards (18 AAC 70) for the protection of the growth and propagation of fish, shellfish, other aquatic life, and wildlife in freshwater.

^{b/} Environmental Protection Agency (EPA, 1991b) water quality criteria for the protection of aquatic life in freshwater.

^{c/} Acute literature toxicity guidelines for aquatic life.

^{d/} µg/L - micrograms per liter.

^{e/} Lowest observed effect level (LOEL).

^{f/} Median threshold value for *Daphnia*.

^{g/} mg/L - milligrams per liter.

The goal of implementing a bioventing system at the site would be to expedite removal of BTEX from both soil and groundwater. As described previously (Section 5), the Bioplume II model NaknekB suggested that a reduction in the source at the site could affect how quickly the dissolved BTEX plume recedes from its current position. For example, the Bioplume II model run NaknekB indicated that a 50 percent reduction in contaminant loading rates would reduce the highest recorded concentration at the site by nearly 75 percent and would begin reducing the overall area of groundwater contamination. A 70 percent reduction in contaminant loading rates is predicted to reduce dissolved contaminant concentrations to levels which can be totally assimilated by the aquifer, thus eliminating detectable concentrations of BTEX in the aquifer. Reductions in soil contamination would ultimately mitigate potential migration into the B-Aquifer and to surface waters at the wetland.

This alternative also includes use of the intrinsic remediation technology as described in Alternative 1. A source search coupled with institutional controls, a predictive risk assessment, and LTM would also be required. POC and LTM wells would be installed and sampled as indicated in the previous section.

6.4 EVALUATION OF ALTERNATIVES

This section provides a comparative analysis of each of the remedial alternatives based on the effectiveness, implementability, and cost criteria. A summary of this evaluation is presented in Section 6.5.

6.4.1 Alternative 1 - Intrinsic Remediation, Source Identification, Institutional Controls with Long-Term Monitoring, and Contingent Predictive Risk Assessment

6.4.1.1 Effectiveness

Section 5 of this document presents the results of the Bioplume II modeling completed to support the intrinsic remediation alternative at the Upper Naknek Site. Two models (NaknekA and NaknekB) were used to illustrate a range of potential future conditions at the site. Model results predicted that natural attenuation mechanisms will significantly limit contaminant migration and reduce contaminant mass in the A-Aquifer. Benzene concentrations should not exceed the federal MCL at the POC wells. Groundwater monitoring at the LTM and POC wells will ensure the protectiveness of this alternative. While this alternative would not cease to be protective if the benzene plume was intercepted by the POC wells, such an instance would indicate that site conditions should be reevaluated.

Alternative 1 is based on the effectiveness of naturally occurring processes that minimize contaminant migration and reduce contaminant mass over time, and the effectiveness of institutional controls. As described earlier, an investigation of the potential effectiveness of naturally occurring processes at the Upper Naknek Site using field data and the Bioplume II model demonstrated that the BTEX plume migration will be significantly limited. The model sensitivity analysis completed for this site (Section 5.5) suggests that even under the most conservative (i.e., worst-case) conditions, the naturally occurring processes at the Upper Naknek Site should reduce contaminant migration so that the maximum distance traveled by the plume in the surface aquifer (or potentially in the B-Aquifer, though not modeled) is unlikely to be beyond the proposed

POC wells. The actual maximum migration distance is likely to be less than the maximum predicted distance of the model simulations (NaknekA), which suggested that the dissolved BTEX plume would migrate no more than 150 feet beyond the observed plume front.

In the shallow aquifer, benzene concentrations should not exceed the federal MCL at the POC wells. Natural attenuation may also remediate potential B-Aquifer contamination. Based on current toluene concentrations measured in monitoring well 506, the extent of contamination in the B-Aquifer is not suspected to be as great as in the A-Aquifer. The LTM and POC networks will help ensure the protectiveness of Alternative 1 for both site aquifers. If benzene was detected in the POC wells, site conditions should be reevaluated.

The effectiveness of this remedial alternative requires that excavations or drilling within the source area be conducted only by properly protected site workers. Reasonable land use assumptions for the plume area indicate that exposure is unlikely unless excavation or drilling activities bring saturated soil to the surface. Long-term land use restrictions will be required to ensure that shallow groundwater will not be pumped or removed for potable use within, and approximately 500 feet in all directions from, the existing BTEX plume. Existing health and safety plans should be enforced to reduce risks from installing and monitoring additional POC and LTM wells.

Concentrations of potential wetland contaminants should be minimal (e.g., below Alaskan surface water and sediment quality levels) because low concentrations of BTEX reaching the wetland waters are further reduced by natural attenuation and the possible enhanced remedial properties of the wetland. Surface water and sediment of the wetland should be sampled annually to verify this prediction. If state standards are exceeded, a predictive risk assessment should be performed to determine if BTEX concentrations will pose any risk to site receptors. Use of this risk assessment in regulatory negotiations should reduce the probability that engineered remedial solutions would need to be implemented.

Source identification through Geoprobe® sampling will help to effectively define the nature and extent of contamination, as the true location of the site contaminant sources is unknown. Additional soil data is expected to support existing natural attenuation conclusions by identifying (and eventually correcting) any potential continuous sources, and verifying the weathered characteristics of fuel at the site.

Compliance with program goals is one component of the long-term effectiveness evaluation criteria. Alternative 1 will satisfy program objectives designed to promote intrinsic remediation as a component of site remediation and to scientifically document naturally occurring processes. Aside from the administrative concerns associated with enforcement of long-term land use restrictions and long-term groundwater monitoring programs, this remedial alternative should provide reliable, continued protection. Model results suggest that the plume is already stable. However, due to uncertainty about how long the source area would continue to produce dissolved BTEX contamination, it is assumed for cost comparison purposes that annual monitoring to insure that dissolved benzene concentrations do not exceed federal MCLs at the POC will continue for approximately 15 years under Alternative 1.

6.4.1.2 Implementability

Alternative 1 is not technically difficult to implement. Installation of LTM and POC wells, Geoprobe® sampling of soils, and annual groundwater, surface water, and sediment monitoring are standard procedures. Long-term management efforts will be required to ensure proper sampling procedures are followed. If a predictive risk assessment is required in response to contaminant concentrations detected in wetland surface waters and sediments, it should be performed with consideration given to other basewide risk assessments [performed as part of the IRP by EMCON (1995)] to minimize the time and cost of the work. Periodic site reviews should be conducted to confirm the adequacy and completeness of LTM data and verify the effectiveness of this remediation approach. There may also be administrative concerns associated with long-term enforcement of groundwater use restrictions. Future land use within the source area may be impacted by leaving contaminated soil and groundwater in place. Regulators and the public will have to be informed of the benefits and limitations of the intrinsic remediation option. Educational programs are not difficult to implement, and the initial regulatory reaction to this alternative has been positive.

6.4.1.3 Cost

The cost of Alternative 1 is summarized in Table 6.4. Existing wells would be used for four of the five LTM well locations. Therefore, capital costs are limited to the construction of five new POC wells and one new LTM well. Included in the \$498,000 total present worth cost estimate for Alternative 1 are the costs of maintaining institutional controls and long-term groundwater, surface water and sediment monitoring for a total of 15 years. In the event that a predictive risk assessment is not necessary (hydrocarbon contamination in wetland media does not exceed State standards), the total present worth cost is estimated at \$468,000.

6.4.2 Alternative 2 - Residual LNAPL Removal Through Bioventing, Intrinsic Remediation, Source Identification, Predictive Risk Assessment, and Institutional Controls with Long-Term Monitoring

6.4.2.1 Effectiveness

The effectiveness of the intrinsic remediation, source identification, predictive risk assessment, institutional controls, and LTM components of this alternative have been described under Alternative 1. Bioventing is an established technology that effectively remediates fuel hydrocarbons in the unsaturated zone via the addition of oxygen to stimulate biodegradation by natural microorganisms that already are present at the site. Previous case studies have shown that significant biodegradation rates can be achieved in cold regions in Alaska (Ong *et al.*, 1994). Thus, bioventing is highly applicable to the removal of soil hydrocarbons, even during phases of soil freeze/thaw cycles.

Assuming the bioventing system removes 50 percent of the residual LNAPL over 5 years, model results suggest that the BTEX plume front should remain near, or no more than 150 feet beyond, its present position. In addition, total BTEX concentrations should diminish in the source area and the central portion of the plume by nearly 75 percent. However, because the bioventing system would not address dissolved BTEX contamination beyond the bioventing injection wells, dissolved BTEX concentrations

TABLE 6.4
ALTERNATIVE 1 - COST ESTIMATE
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

<u>Capital Costs</u>	<u>Cost</u>
Design/Construct 5 POC Wells and 1 LTM Well	\$29,000
Source Identification (Geoprobe®)	\$26,000
Predictive Risk Assessment	\$30,000
 <u>Operation, Maintenance and Monitoring Costs</u>	 <u>Annual Cost</u>
Conduct Annual Groundwater Monitoring of 11 wells, Surface water Monitoring at 4 Locations, and Sediment Monitoring at 4 Locations (15 years)	\$5,000
Maintain Institutional Controls (15 years)	\$12,000
Public Education (15 years)	\$6,000
Project Management (15 years)	\$8,000
Land use restriction proceedings (unit cost)	\$25,000
 <u>Present Worth of Alternative 1</u> ^{a/}	 \$498,000 ^{b/}

^{a/} Based on an annual inflation factor of 5 percent and a 15 percent contingency.

^{b/} If a predictive risk assessment is not needed, the present worth cost is \$468,000.

downgradient would continue to be reduced by intrinsic remediation alone. As with Alternative 1, this alternative would require long-term land use restrictions and enforcement of health and safety plans to reduce risks from installing and monitoring LTM and POC wells.

Alternative 2 would expedite removal of both soil and groundwater contaminants and provide continuous protection, with no anticipated risk from temporary bioventing failures. This alternative is based on the premise that natural attenuation is effective at inhibiting further site contamination, although bioventing will enhance remediation of the site. As shown by model NaknekB, bioventing would gradually decrease plume concentration without immediate changes in the downgradient extent of the plume. This alternative complies with the program goals because intrinsic remediation remains the predominant decontamination method for the site. However, this remedial alternative will result in the generation of other wastes (e.g., drill cuttings) requiring treatment and/or disposal.

As in Alternative 1, it is assumed that monitoring, to ensure that dissolved benzene concentrations do not exceed federal MCLs at the POC, will continue for approximately 10 years under Alternative 2. A predictive risk assessment would also determine if an exposure pathway in the wetland is incomplete, thus supporting the use of natural attenuation. Annual groundwater, surface water, and sediment monitoring will be required during that time to ensure that LNAPL recovery and intrinsic remediation has uniformly reduced all BTEX concentrations to levels below MCLs.

6.4.2.2 Implementability

Installation and operation of a bioventing unit is relatively simple, with some logistical concerns about power connections and locations of the bioventing blowers. Potential impact to site use would be moderate as blower lines and injection wells would need to be placed at many locations at the site and may inhibit travel in certain areas. The technical and administrative implementability concerns associated with the intrinsic remediation and LTM component of this remedial alternative are identical to those discussed in Alternative 1

6.4.2.3 Cost

The estimated capital and operating costs of Alternative 2 are shown in Table 6.5. The total present worth cost of Alternative 2 is \$1,561,000. The increased cost of Alternative 2 over Alternative 1 is the result of the addition of the bioventing system. Compared to Alternative 1, this bioventing system would reduce the anticipated time needed for LTM. Monitoring would be continued for 10 years to verify that the plume continues to degrade and that no part of the plume reaches the POC wells. Annual LTM of groundwater, surface water, and sediments would continue for 10 years to ensure that intrinsic remediation is preventing BTEX concentrations exceeding MCLs from reaching the POC or exceeding State surface water and sediment criteria in the wetland. In the event that a predictive risk assessment is not necessary, the estimated present worth cost of Alternative 2 would be \$1,531,000.

6.5 RECOMMENDED REMEDIAL APPROACH

Two remedial alternatives have been evaluated for remediation of the shallow groundwater at The Upper Naknek Site. Protection of wetland surface waters and B-Aquifer groundwater were also considered in the decision process. Components of the evaluated alternatives include source identification, predictive risk assessment, bioventing, intrinsic remediation with LTM, and institutional controls. Table 6.6 summarizes the results of the evaluation based upon effectiveness, implementability, and cost criteria. On the basis of this evaluation, Parsons ES recommends Alternative 1. Alternative 1 was selected because natural attenuation mechanisms alone should be effective enough to protect site receptors. Furthermore, capital expenditures and site impact would be minimized with this alternative. Alternative 2 offers a method to expedite groundwater and soil clean up, but little reduction in plume migration and downgradient risk reduction in the short term.

Both alternatives make maximum use of intrinsic remediation mechanisms to reduce plume migration and toxicity. Alternative 2 would provide some additional protection

TABLE 6.5
ALTERNATIVE 2 - COST ESTIMATE
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON AIRPORT, ALASKA

<u>Capital Costs</u>	<u>Cost</u>
Design/Construct 5 POC Wells and 1 LTM Well	\$29,000
Source Identification (Geoprobe® Sampling)	\$25,600
Predictive Risk Assessment	\$30,000
Installation of Bioventing Unit	\$800,000
<u>Operation, Maintenance and Monitoring Costs</u>	<u>Annual Cost</u>
Conduct Annual Groundwater Monitoring of 11 wells, Surface water Monitoring at 4 Locations, and Sediment Monitoring at 4 Locations (10 Years)	\$5,000
Operation and Maintenance of Bioventing System (5 years)	\$28,000
Monitoring of Bioventing System Performance (5 years)	\$20,000
Maintain Institutional Controls (10 years)	\$12,000
Public Education (10 years)	\$6,000
Project Management (10 years)	\$8,000
Land use restriction proceedings (unit cost)	\$25,000
<u>Present Worth of Alternative 2 ^{a/}</u>	\$1,561,000

^{a/} Based on an annual inflation factor of 5 percent and a 15 percent contingency.

^{b/} If a predictive risk assessment is not needed, the present worth cost is \$1,531,000.

against further plume migration, but would still rely on intrinsic remediation mechanisms to reduce plume toxicity downgradient of the proposed bioventing system. Implementation of Alternative 2 would reduce the time frame for remediation, but would require a greater capital expenditure.

TABLE 6.6

**SUMMARY OF REMEDIAL ALTERNATIVES EVALUATION
GROUNDWATER AND SURFACE WATER REMEDIATION
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA**

Remedial Alternative	Effectiveness	Implementability	Present Worth Cost Estimate
Alternative 1 -Intrinsic Remediation -Source Identification -Long-Term Monitoring -Contingent Predictive Risk Assessment	Contaminant mass and volume will be significantly reduced and plume migration maintains, or recedes from, existing conditions. MCLs for BTEX are not likely to be exceeded at POC wells in either the A-Aquifer or B-Aquifer. Surface water contamination should also be mitigated by natural attenuation processes. A predictive risk assessment can be performed to address the expected current or future risk from potential wetland contamination if contaminant levels in the wetland exceed State promulgated criteria.	Readily implementable. Long-term management, groundwater use controls and monitoring required for an estimated 15 years. Minimal exposure of human or ecological receptors at the site, as long as conditions remain the same. If MCLs are exceeded in POC wells and/or if a predictive risk assessment is performed and suggests possible risk at the site, additional remedial work may be required.	\$498,000 ^{a/}
Alternative 2 -Intrinsic Remediation -Source Identification -Long-Term Monitoring -Residual LNAPL Removal Through Bioventing -Contingent Predictive Risk Assessment	Similar to Alternative 1, with the installation of a bioventing unit to expedite biological remediation of soil contamination, thereby increasing the rate of remediation of contaminated groundwater. Less likely that MCLs will be exceeded at POC locations.	Readily implementable. Bioventing technology is proven, even in cold climates. As in alternative 1, minimal exposure of human or ecological receptors is expected as long as site conditions remain unchanged. If MCLs are exceeded in POC wells and/or if a predictive risk assessment is performed and suggests possible risk at the site, additional remedial work may be required.	\$1,561,000 ^{b/}

^{a/} Present worth cost is reduced to \$468,000 if a predictive risk assessment is not needed.

^{b/} Present worth cost is reduced to \$1,531,000 if a predictive risk assessment is not needed.

Both of the remedial alternatives are implementable, and both alternatives effectively reduce potential hydrocarbon migration and toxicity. Both alternatives should be acceptable to the public and regulatory agencies because they are protective of human health and the environment and reduce groundwater contamination in a relatively short time frame. Implementation of either alternative will require land use and groundwater use controls to be enforced for a minimum of 10 to 15 years (depending on the remedial alternative selected), along with annual groundwater, surface water, and sediment monitoring for the same period (unless evaluation of future sampling data indicates that a shorter time frame is appropriate).

The final evaluation criterion used to compare each of the two remedial alternatives was cost. Alternative 2 is substantially more expensive than Alternative 1, and downgradient plume migration is not significantly limited until more than 50 percent of the soil contaminant mass is removed. Risk is not greatly minimized in the short term by Alternative 2, therefore, Alternative 1 is preferred. If new sources are discovered at the site, additional evaluation of remedial alternatives may be necessary.

SECTION 7

LONG-TERM MONITORING PLAN

7.1 OVERVIEW

In keeping with the requirements of the preferred remedial alternative for the Upper Naknek Site (intrinsic remediation with LTM, source identification, and contingent predictive risk assessment), a LTM plan must be developed. The purpose of this component of the preferred remedial alternative for the Upper Naknek Site is to assess site conditions over time and confirm the effectiveness of naturally occurring processes at reducing contaminant mass and minimizing contaminant migration, and evaluate the need for additional remediation.

The LTM plan consists of identifying the location of two separate groundwater monitoring networks and developing a groundwater sampling and analysis strategy to demonstrate attainment of the remediation goals for groundwater (A- and B-Aquifers), surface water, and sediment in the wetland, and to verify the predictions of the Bioplume II model developed for the Upper Naknek Site. The strategy described in this section is designed to monitor plume migration in the A- and B-Aquifers, and possibly the wetland, over time and to verify that intrinsic remediation is occurring at rates sufficient to protect potential receptors in these aquifers and in wetland waters. In the event that data collected under this LTM program indicate that naturally occurring processes are insufficient to protect human health and the environment, a re-evaluation of contingency controls would be necessary.

7.2 MONITORING NETWORKS FOR GROUNDWATER

Two separate sets of wells will be installed at the site as part of the intrinsic remediation with LTM remedial alternative. The first set will consist of five LTM well locations in, upgradient, and downgradient of the observed BTEX plume to verify the results of the Bioplume II modeling effort and to ensure that natural attenuation is occurring at rates sufficient to minimize plume expansion. This network of wells will consist of existing wells and one proposed well screened within the A-Aquifer to provide short-term confirmation and verification of the quantitative groundwater modeling results. The second set of groundwater monitoring wells will include three nested POC well locations located along a line approximately 700 feet downgradient from MW-51 or ESMW-8 (which are near the source of groundwater contamination). The purpose of the POC wells is to verify that no BTEX compounds exceeding federal MCLs migrate beyond the area under institutional control. This network will consist of three groundwater monitoring wells screened across the middle 5 feet of the shallow aquifer and three wells screened across the top 10 feet of the B-Aquifer. The LTM and POC

wells will be sampled for analysis of the parameters listed in Tables 7.1 and 7.2, respectively.

7.2.1 Long-Term Monitoring Wells

At five locations, groundwater wells within, upgradient, and downgradient of the existing BTEX contaminant plume will be used to monitor the effectiveness of intrinsic remediation in reducing total contaminant mass and minimizing contaminant migration in the shallow aquifer of the Upper Naknek Site. One well located upgradient of the existing plume (MW-54) will be monitored for background values. Of the remaining locations, two are in the anaerobic treatment zone (at MW-51 and ESMW-8), and two are in the aerobic treatment zone (at 506 and ESMW-13). The LTM well locations are not located along the centerline of the plume in order to protect wetland integrity by avoiding drilling within its boundaries.

At all four of the five LTM locations, an existing well will be used as an A-Aquifer LTM well. Existing shallow (A-Aquifer) LTM locations will be provided by monitoring wells MW-54, MW-51, ESMW-8A and ESMW-13A. To avoid creating potential contaminant migration pathways between the A-Aquifer and B-Aquifer, no new wells will be drilled through the A-Aquitard within the plume boundaries. A new well drilled near the existing B-Aquifer monitoring well (506) will be used as a fifth LTM well. This network will supplement the POC wells in the A- and B-Aquifers to provide early confirmation of model predictions in the A-Aquifer and to allow additional response time if contamination is migrating downgradient in the A-aquifer or if B-Aquifer BTEX concentrations increase. All LTM wells will be sampled and analyzed for the parameters listed in Table 7.1 to verify the effectiveness of the intrinsic remediation remedial alternative. Figure 7.1 shows the proposed locations of the LTM wells.

7.2.2 Point-of-Compliance Wells

Three nested POC monitoring well locations will be installed approximately 250 feet downgradient of the existing BTEX plume front (approximately 700 feet downgradient of the estimated contaminant sources). Figure 7.1 shows the proposed locations of these wells. The purpose of the nested POC wells is to verify that no contaminated groundwater exceeding federal MCLs migrates beyond the area under institutional control. Although model results suggest that the contaminant plume will not migrate beyond this location in the shallow aquifer at concentrations exceeding chemical-specific federal MCLs, these nested POC wells are the technical mechanisms used to demonstrate protection of human health and the environment and compliance with site-specific numerical remediation goals. Although a modeling effort was not applied to potential contamination in the B-Aquifer, the same RAO used for the A-Aquifer will also apply to the B-Aquifer. Nested POC wells will be installed and monitored for the parameters listed in Table 7.2 to assure that the selected remedy is providing the anticipated level of risk reduction and remediation in the A- and B-Aquifers of the site.

Data presented in this report concerning the nature and extent of contamination at the site suggest that 5-foot screens across the middle of the shallow aquifer will be sufficient to intercept the contaminant plume at this site (the saturated interval is relatively thin). Monitoring well ESMW-14A will be used as one of the three shallow POC wells. Deep wells will have 10-foot screens, consistent with the other deep well at the site (e.g.,

TABLE 7.1
LONG-TERM MONITORING ANALYTICAL PROTOCOL
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Ferrous (Fe^{2+})	Colorimetric A3500-Fe D	Field only	Elevated ferrous iron concentrations may be indicative of the anaerobic biodegradation process of iron reduction	Annually	Collect 100 mL of water in a glass container; acidify with hydrochloric acid per method	Field
Ferrous (Fe^{2+})	Colorimetric HACH 25140-25	Alternate method; field only	Elevated ferrous iron concentrations may be indicative of the anaerobic biodegradation process of iron reduction	Annually	Collect 100 mL of water in a glass container	Field
Temperature	E170.1	Field only	Metabolism rates for microorganisms depend on temperature	Annually	N/A	Field
Dissolved Oxygen	Dissolved oxygen meter	Refer to Method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume II model; concentrations less than 1 mg/L generally indicate an anaerobic pathway	Annually	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately; alternately, measure dissolved oxygen in situ	Field
pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods ^{a/}	Aerobic and anaerobic processes are pH-sensitive	Annually	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field
Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Annually	Collect 100–250 mL of water in a glass or plastic container	Field
Nitrate (NO_3^{-})	IC method E300 or method SW9056; colorimetric, method E353.2	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for microbial respiration if oxygen is depleted	Annually	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C; analyze within 48 hours	Fixed-base
Water	HACH Alkalinity test kit model AL AP MG-L	Phenolphthalein method	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 100–250 mL of water in a glass or plastic container	Field

TABLE 7.1 (Concluded)
LONG-TERM MONITORING ANALYTICAL PROTOCOL
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

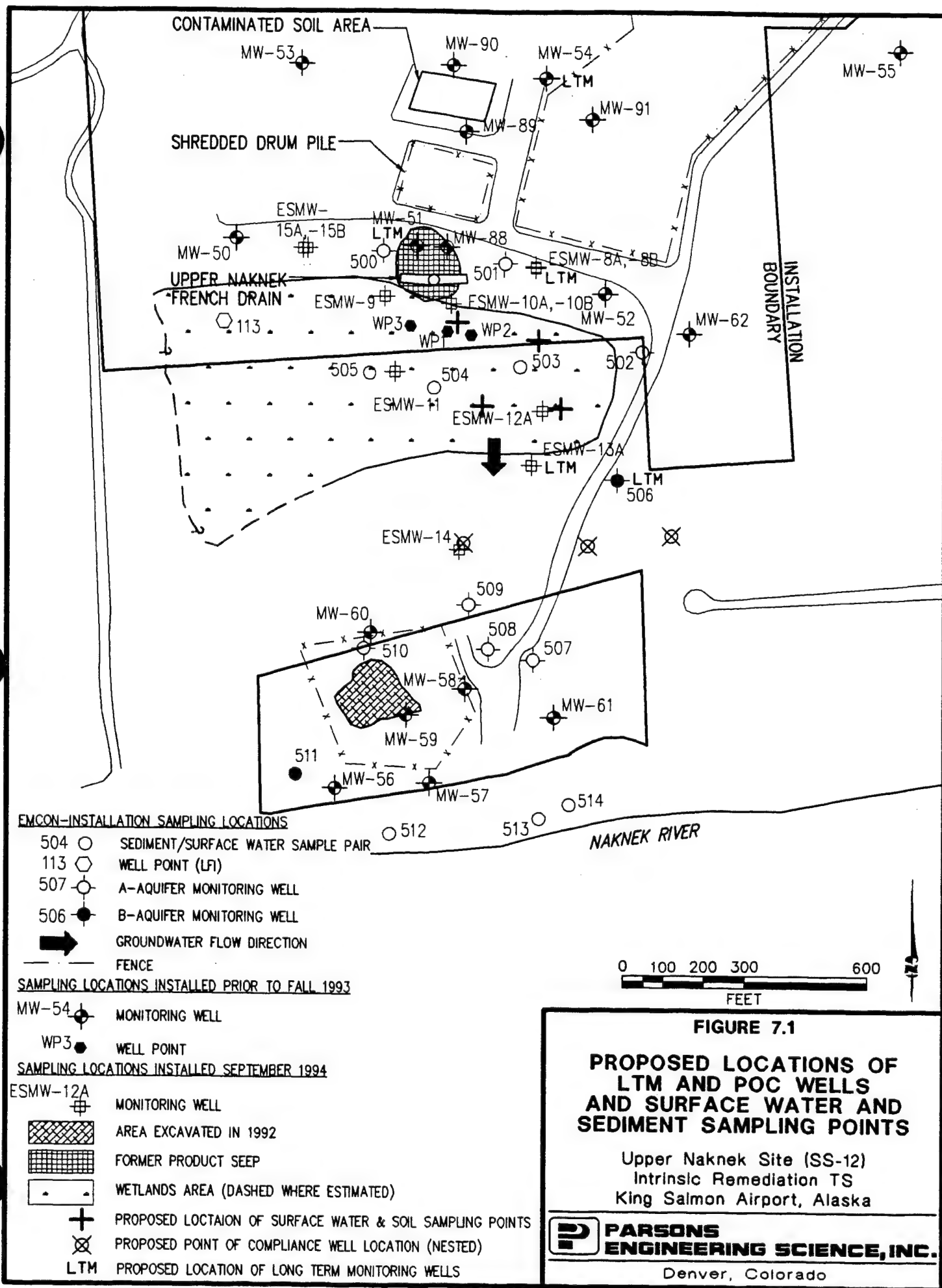
Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Sulfate (SO_4^{2-})	IC method E300 or method SW9056 or HACH SulfaVer 4 method	Method E300 is a Handbook method; method SW9056 is an equivalent procedure. HACH method is Photometric	Substrate for anaerobic microbial respiration	Annually	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base or field (for HACH method)
Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of groundwater influences and is influenced by biologically mediated reactions; the redox potential of groundwater may range from more than 200 mV to less than -400 mV	Annually	Collect 100-250 mL of water in a glass container, filling container from bottom; analyze immediately	Field
Methane	RSKSOP-114 modified to analyze water samples for methane by headspace sampling with dual thermal conductivity and flame ionization detection.	Method published and used by the US Environmental Protection Agency Robert S. Kerr Laboratory	The presence of methane suggests BTEX degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis)	Annually	Collect water samples in 40 mL volatile organic analysis (VOA) vials with butyl gray/Teflon-lined caps (zero headspace); cool to 4°C	Fixed-base
Aromatic hydrocarbons (BTEX)	Purge and trap GC method SW8020	Handbook method; analysis may be extended to higher molecular weight alkylbenzenes	BTEX is the primary target analyte for monitoring natural attenuation; BTEX concentrations must also be measured for regulatory compliance	Annually	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base

a/ Protocol methods are presented by Wiedemeier *et al.*, 1994

TABLE 7.2
POINT-OF-COMPLIANCE MONITORING ANALYTICAL PROTOCOL
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Temperature	E170.1	Field only	Well development	Annually	N/A	Field
Dissolved Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume model; concentrations less than 1 mg/L generally indicate an anaerobic pathway	Annually	Collect 300 mL of water in bottles; analyze immediately; alternately, measure dissolved oxygen in situ	Field
pH	E150.1/SW/9040, direct reading meter	Protocols/Handbook methods ^a	Aerobic and anaerobic processes are pH-sensitive	Annually	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field
Conductivity	E120.1/SW/9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Annually	Collect 100–250 mL of water in a glass or plastic container	Field
Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of groundwater influences and is influenced by biologically mediated reactions; the redox potential of groundwater may range from more than 200 mV to less than -400 mV	Annually	Collect 100–250 mL of water in a glass container, filling container from bottom; analyze immediately	Field
Aromatic hydrocarbons (BTEX)	Purge and trap GC method SW/8020	Handbook method; analysis may be extended to higher molecular weight alkylbenzenes	BTEX is the primary target analyte for monitoring natural attenuation; BTEX concentrations must also be measured for regulatory compliance	Annually	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base

^a Protocol methods are presented by Wiedemeier *et al.*, 1994



monitoring well 506), with the well screens extending down from the top of the aquifer. Figure 7.2 is a proposed groundwater monitoring well completion diagram for both the LTM well and the POC wells.

7.3 MONITORING NETWORK FOR WETLAND SURFACE WATER AND SEDIMENT

A pattern of surface water and sediment sampling will be implemented to ensure that the RAO for these media in the wetland is being achieved. These sampling locations will be located within the wetland and downgradient of observed wetland locations exhibiting underlying groundwater BTEX contamination. The surface water and sediment sampling will verify that wetland hydrocarbon contamination is not accumulating at levels that exceed Alaskan surface water and sediment quality criteria. Sediment samples will be collected from the first 12 inches of sediment at four different locations. The pattern for sampling was designed to take two samples of wetland sediments downgradient from each of the two observed source areas. Surface water sampling will also be performed at these locations. Table 7.3 lists the parameters to be measured for surface water. Table 7.4 lists the parameters to be analyzed for sediments. Figure 7.1 shows the location of proposed surface water and sediment sampling locations.

7.4 GROUNDWATER AND WETLAND SURFACE WATER SAMPLING

To ensure that sufficient contaminant removal is occurring at the Upper Naknek Site to protect human health and the environment and meet site-specific remediation goals, the long-term groundwater monitoring plan includes a comprehensive sampling and analysis plan. Surface water and groundwater from LTM and POC wells will be sampled and analyzed annually to verify that naturally occurring processes are effectively reducing contaminant mass and mobility. Reductions in toxicity will be implied by mass reduction. The sampling and analysis plan will also be aimed at assuring intrinsic remediation can achieve site-specific remediation concentration goals for BTEX compounds and protect human health and the environment.

7.4.1 Analytical Protocol

All LTM and POC wells in the LTM program will be sampled annually and analyzed to determine compliance with chemical-specific remediation goals and to verify the effectiveness of intrinsic remediation at the site. Locations for POC, LTM, and surface water sampling are shown in Figure 7.1. Water level measurements will be made in the POC and LTM wells during each sampling event. Groundwater samples will be analyzed for the parameters listed in Tables 7.1 and 7.2. Surface water samples will be analyzed for the parameters listed in Table 7.3. A site-specific groundwater and surface water sampling and analysis plan should be prepared prior to initiating the LTM program.

7.4.2 Sampling Frequency

Each of the LTM, POC, and surface water sampling locations will be sampled once each year for 15 years. If the data collected during this time period supports the anticipated effectiveness of the intrinsic remediation alternative at this site, it may be possible to reduce or eliminate sampling. If the data collected at any time during the

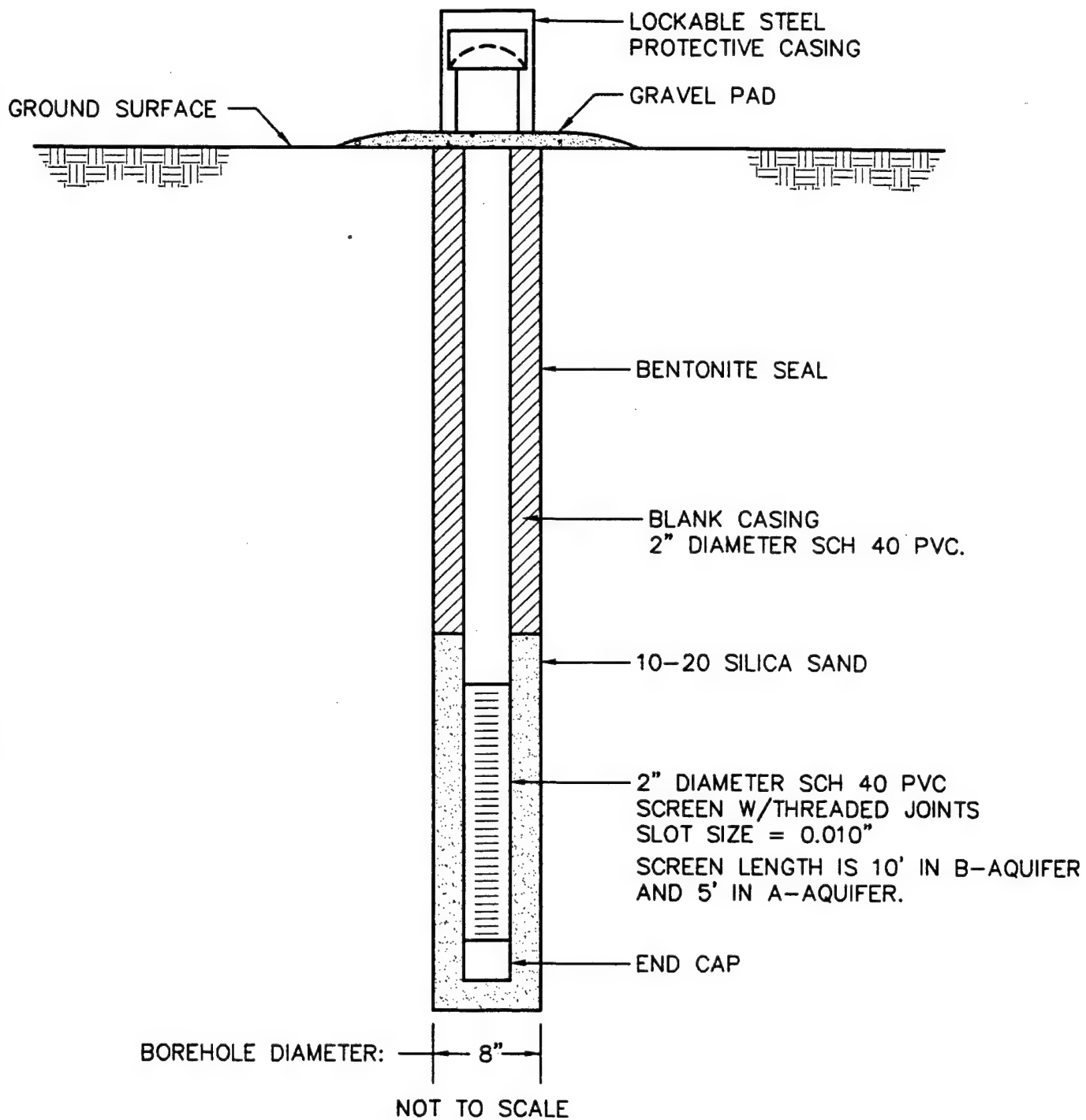


FIGURE 7.2

**PROPOSED POC AND LTM
MONITORING WELL
COMPLETION DIAGRAM**

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska



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TABLE 7.3
WETLAND SURFACE WATER MONITORING ANALYTICAL PROTOCOL
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Total Petroleum Hydrocarbons	SW8015 (Modified)	Handbook method; reference is the California LUFT manual	TPH is used as a surface water quality standard and applies to wetland surface waters	Annually	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Aromatic hydrocarbons (BTEX)	Purge and trap GC method SW8020	Handbook method; analysis may be extended to higher molecular weight alkylbenzenes	BTEX is the primary target analyte for monitoring natural attenuation; BTEX concentrations must also be measured for regulatory compliance	Annually	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base

TABLE 7.4
WETLAND SEDIMENTS MONITORING ANALYTICAL PROTOCOL
UPPER NAKNEK SITE (SS-12)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data are used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Annually	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Aromatic hydrocarbons (benzene, toluene, ethylbenzene, and xylene [BTEX]; trimethylbenzene isomers)	Purge and trap gas chromatography (GC) method SW8020	Handbook method modified for field extraction of soil using methanol	Data is used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Annually	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base

monitoring period indicate the need for additional remedial activities at the site, sampling frequency should be adjusted accordingly.

7.5 WETLAND SEDIMENT SAMPLING

7.5.1 Analytical Protocol

Wetland sediment will be sampled to evaluate if intrinsic remediation is inhibiting contaminant migration in sediment and groundwater to prevent buildup of petroleum hydrocarbon contaminant concentrations above promulgated Alaskan sediment quality criteria. Revised Alaskan sediment quality criteria should be available by April 1995. Sediment samples will be extracted as a composite of the top 1 foot of sediment, or as otherwise directed by Alaskan standards, at the locations designated in Figure 7.1. Sediment samples will be analyzed for the parameters listed in Table 7.4. A site-specific sediment sampling and analysis plan should be prepared prior to initiating the sediment sampling program.

7.5.2 Sampling Frequency

Each of the sediment sampling locations will be sampled once each year for 15 years. If the data collected during this time period supports the anticipated effectiveness of the intrinsic remediation alternative at this site, the sampling frequency can be reduced to every other year, or eliminated. If the data collected at any time during the monitoring period indicate the need for additional remedial activities at the site, sampling frequency should be adjusted accordingly.

SECTION 8

CONCLUSIONS AND RECOMMENDATIONS

This report presents the results of a TS conducted to evaluate the use of intrinsic remediation (natural attenuation) for remediation of fuel-hydrocarbon-contaminated groundwater at the Upper Naknek Site (SS-12), King Salmon Airport, Alaska. Specifically, the finite-difference groundwater model Bioplume II was used in conjunction with site-specific geologic, hydrologic, and laboratory analytical data to simulate the migration and biodegradation of fuel hydrocarbon compounds dissolved in groundwater. Groundwater contaminant and geochemical data strongly suggest that biodegradation of fuel hydrocarbons at the site is occurring through aerobic respiration, iron reduction, and methanogenesis. Groundwater contaminant data also identify two spill sources at the Upper Naknek Site have produced dissolved BTEX plumes that merge together in the shallow groundwater. Both spill sources (defined as the eastern and western sources) were included in this TS to evaluate the use of intrinsic remediation for remediation of dissolved fuel contamination at this site.

The results of this study suggest that natural attenuation of BTEX compounds is occurring at the Upper Naknek Site to the extent that the dissolved concentrations of these compounds in groundwater and surface water should be reduced to levels below current regulatory guidelines long before potential downgradient receptors could be adversely affected (i.e., the potential contaminant migration pathway will not be complete for any of the potential receptors described in Section 6.2). On the basis of the distance to potential downgradient receptors (at least 700 feet to residences from the observed plume front) and rates of BTEX plume migration and degradation predicted by models NaknekA and NaknekB, Parsons ES is recommending natural attenuation, institutional controls, source identification, LTM, and a contingent predictive risk assessment as components of the remedial alternative for BTEX-impacted groundwater and surface water. Construction activities in the plume area and groundwater use in and downgradient from the plume area should be restricted for a period of approximately 15 years.

To collect the data necessary for the intrinsic remediation demonstration, Parsons ES and EPA researchers collected soil and groundwater samples from the site. Physical and chemical data collected under this program were supplemented with data collected during previous site characterization events. Site-specific geologic, hydrologic, and laboratory analytical data were then used in the Bioplume II numerical groundwater model to simulate the effects of advection, dispersion, sorption, and biodegradation on the fate and transport of the dissolved BTEX plume in the shallow aquifer. Extensive site-specific data were used for model calibration and implementation. Model parameters that could not be obtained from existing site data were estimated using widely accepted literature values for sediments similar to those found at the site. Conservative aquifer parameters

were used to construct the Bioplume II model for this study, and therefore, the model results are conservative in nature.

Although the original focus of this report was to characterize and model BTEX contamination in the shallow aquifer (A-Aquifer), suspected contamination was identified in a wetland downgradient of the Upper Naknek Site and also in the lower confined aquifer (B-Aquifer). The topography and hydrogeology of the Upper Naknek site creates a wetland that receives discharging groundwater a few hundred feet south of the contaminant sources; thus, a completed migration pathway from groundwater to surface water exists. However, BTEX contamination in the surface water and sediment has not been documented by surface water and sediment sample results. Contaminated groundwater is migrating beneath the wetland and may introduce contamination into the wetland.

Low levels (less than 7 $\mu\text{g/L}$) of toluene contamination were detected in monitoring well 506, suggesting potential contamination of the B-Aquifer. Only monitoring well 506 is screened in the B-Aquifer, and therefore the extent of contamination in the B-Aquifer has not been ascertained. However, flow characteristics of the B-Aquifer are believed to be similar to the A-Aquifer, and groundwater likely flows south toward the Naknek River. Toluene contamination detected in the well may have originated from upgradient sources through a breach in the confining layer between the A-Aquifer and B-Aquifer.

The predicted fate and transport of contaminants in the A-Aquifer, the B-Aquifer, and the wetland were evaluated. The original scope of this study was only directed towards characterization and modeling of shallow groundwater contamination. Suspected contamination in wetland and B-Aquifer media was addressed using qualitative analysis because insufficient data were available to conduct a quantitative analysis of contaminant fate and transport in these media. In general, natural attenuation is predicted to mitigate contaminant migration and concentrations in any site media to below federal or state MCLs. Potential human receptor exposure to site media was considered extremely low, especially for wetland waters. Ecological receptors are most likely to be exposed to surface water contamination at the wetland.

To simulate site conditions in the groundwater model (NaknekA), it was assumed that conditions that produced the calibrated model (including BTEX loading rates) would persist for the duration of the 10 year simulation. This a conservative scenario, because BTEX loading rates should decrease over time as residual LNAPL (or possibly mobile LNAPL) in the source area weathers and is degraded by biota present in the soil column. This model suggested that the plume would migrate a maximum of 150 feet beyond the limits observed in 1994 before stabilizing. Model NaknekB assumed that bioventing would result in a 50 percent reduction in BTEX loading rates over a 5 year period. Results of this model suggested that the plume would migrate the same distance as in model NaknekA before stabilizing, and that dissolved BTEX concentrations near the source area would be reduced by nearly 82 percent.

Actual dissolved BTEX degradation rates observed during LTM for groundwater at the site will probably be greater than predicted by either model. This will result in a shorter plume migration distance than predicted by model NaknekA. The main uncertainty in the model simulations for this site is the time frame within which

contaminant mass loading into the aquifer will be reduced to the point that natural attenuation mechanisms can degrade the dissolved BTEX plume to below detectable levels. Model results suggest that this will occur when loading rates from soil contamination decrease by about 70 percent. However, results of both models suggest that biodegradation mechanisms operating at the site should be quite effective in preventing migration of dissolved BTEX compounds introduced by dissolution within the source area, particularly as the volume of residual LNAPL in the source area diminishes.

Toluene concentrations in the B-Aquifer at monitoring well location 506 were below the federal MCL of 700 $\mu\text{g/L}$. Contamination in the B-Aquifer is also susceptible to natural attenuation mechanisms, with anaerobic processes expected to control the biodegradation potential of the aquifer because of inhibited reaeration. Contaminant concentrations reaching the B-Aquifer should be much lower than observed in the A-Aquifer, because of the preferential migration of BTEX contamination through the A-Aquifer across the top of the A-Aquitard. However, the extent and concentration of B-Aquifer contamination has not been defined, and the natural attenuation option for the B-Aquifer should be supported through LTM. Detection of BTEX compounds exceeding POC criteria at POC locations will require reevaluation of the natural attenuation remedial option.

Parsons ES recommends that a source identification survey be conducted through additional soil sampling. This survey is intended to fully define source characteristics such as continuity of the soil sources and the spatial extent of impacted soil. For expedient collection of soil samples, use of a Geoprobe[®] apparatus is recommended. New information regarding source characteristics may alter predicted times for hydrocarbon plume stabilization or retreat. Further source identification will also determine if any undetected LNAPL sources are present that threaten the quality of soil and groundwater and that may affect the current model predictions.

To verify the results of the Bioplume II modeling effort, and to ensure that natural attenuation is occurring at rates sufficient to protect potential groundwater receptors in both the A- and B-Aquifers, groundwater from five proposed LTM well locations should be sampled annually and analyzed for the parameters listed in Table 7.1. LTM well locations are described in Section 7. In addition, three nested POC groundwater monitoring well locations should be installed downgradient from the predicted maximum travel distance of the BTEX plume and sampled annually for the parameters listed in Table 7.2. Figure 7.1 shows suggested locations for the POC wells. Both POC and LTM wells should be sampled annually for 15 years. If dissolved BTEX concentrations in groundwater in the POC wells are found to exceed the federal MCLs of 5 $\mu\text{g/L}$ for benzene, 1,000 $\mu\text{g/L}$ for toluene, 700 $\mu\text{g/L}$ for ethylbenzene, or 10,000 $\mu\text{g/L}$ for total xylenes, additional evaluation or corrective action may be necessary at this site.

Petroleum hydrocarbons entering the wetland at the Upper Naknek Site are subject to the same natural attenuation mechanisms as hydrocarbons in groundwater. The natural attenuation potential of the wetland will likely exceed that of the groundwater because the wetland has the additional benefits of increased organic content and surface area that will enhance degradation and volatilization of BTEX compounds. The surface area of the wetland also increases the reaeration potential for aerobic biodegradation and will allow photooxidation of BTEX contaminants at the wetland surface. These abilities of wetlands to effectively remove toxins such as BTEX compounds is well documented (see, for

example, Meyer, 1985; Phillips *et al.*, 1993; Wolverton, 1987). Model predictions and site data suggest that BTEX concentrations in groundwater at the wetland will remain at or below 200 µg/L, so potential surface water concentrations are expected to be lower than observed groundwater concentrations. Hence, BTEX concentrations in soils or surface water of the wetland are expected to be very low.

To verify that natural attenuation is reducing possible contamination in surface water and sediment of the wetland to below state surface water and sediment criteria, sediment and surface water at four proposed locations should be sampled annually and analyzed for parameters in Tables 7.3 and 7.4. Background surface water and sediment samples should also be taken for total hydrocarbon measurements to correct for potential interferences from natural sources (e.g., organic acids, humates, and suspended materials) that may elevate sample results. Current surface water quality standards for the State of Alaska specify limits of 15 µg/L for TPH and 10 µg/L for total aromatic hydrocarbons to protect fresh water for the growth and propagation of fish, shellfish, other aquatic life, and wildlife (10 AAC 70.020). No promulgated sediment standards currently exist for the State of Alaska. These criteria are subject to change based on new promulgated surface water and sediment standards to be released in April 1995. In the event that these state criteria are exceeded above background levels, Parsons ES recommends that a predictive risk assessment be performed, in conjunction with annual surface water and sediment sampling, to determine if wetland contamination will remain below target risk values to be defined in that assessment. The risk evaluation will be used to determine recommended site-specific risk-based action levels as the new RAO for the affected wetland media. If these target risk values are above current Alaskan surface water or sediment criteria for BTEX and TPH contamination, regulatory approval must be gained before the intrinsic remediation option can be implemented at the wetland.

Parsons ES recommends that a formal request be made to the US Army Corps of Engineers for an official wetland status. If the USACE determines that the wetland has jurisdictional designated status, more stringent soil and water quality criteria may apply to the wetland.

SECTION 9

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APPENDIX A

BORING LOGS, WELL COMPLETION DIAGRAMS, AND SLUG TEST RESULTS

GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: ESMW-8B	CONTRACTOR: AIR FORCE	DATE SPUD: 9/20/94
CLIENT: AFCEE	RIG TYPE: CME 55	DATE CMPL.: 9/20/94
JOB NO.: 722450.11	DRLG METHOD: HOLLOW STEM AUGER	ELEVATION: 29.15 FEET ABOVE MLWL
LOCATION: KING SALMON AFS	BORING DIA.: 10 INCH OD	TEMP: 45 F
GEOLOGIST: KC	DRLG FLUID: NONE	WEATHER: OVERCAST, WINDY
COMMENTS: BACKGROUND PID = 2.8 ppm		

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample		Sample Type	Penet Res	PID(ppm)	WKSPE PID(ppm)	TOTAL BTEX(ppm)	TPH (ppm)	
					No.	Depth (ft)							
	1		SM	No Sample. FILL.			CONTINUOUS CORE						
	5				Brown, silty sand to sandy silt FILL. Organic matter present.								
			SP	Grey, fine- to medium-grained SAND. Strong hydrocarbon odor. Wet.	4-9				2.8				
					SAA. Strong hydrocarbon odor.					299			
	10												
			SW										
	15				SAA turning brown at 16 feet bgs.					65.9			
										27.7			
			GW	Brown, sandy SILT to silty SAND.	14-19			71.4					
					Brown, silty, sandy GRAVEL with pebbles.				2.8				
	20				19-21			31.4					
				Bottom of hole at 21 feet bgs.									
	25												
	30												
	35												

NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB



Water level drilled

GEOLOGIC BORING LOG

Upper Naknek Site (SS-12)
 Intrinsic Remediation TS
 King Salmon Airport, Alaska





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GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: ESMW-9A CONTRACTOR: AIR FORCE DATE SPUD: 9/19/94
 CLIENT: AFCEE RIG TYPE: HAND DATE CMPL.: 9/19/94
 JOB NO.: 722450.11 DRLG METHOD: HOLLOW STEM AUGER ELEVATION: 21.60 FEET ABOVE MI
 LOCATION: KING SALMON AFS BORING DIA.: 3 INCHES TEMP: 50 F
 GEOLOGIST: KC DRLG FLUID: NONE WEATHER: CLEAR, WINDY
 COMMENTS: BACKGROUND PID = 2.6 ppm


Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample		Penet Res	PID(ppm)	WKSPCE PID(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
					No.	Depth (ft)					
	1		Pt	Dark brown PEAT. Saturated at 6".							
	5		SP	Dark brown, fine- to medium-grained SAND. Upper 0.5 feet has increased silt. Turning grey at 3.5 feet bgs.							
				Formation frozen at 7.5 feet bgs. Bottom of hole at 7.5 feet bgs.							
	10										
	15										
	20										
	25										
	30										
	35										

NOTES

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 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB

 Water level drilled

GEOLOGIC BORING LOG

Upper Naknek Site (SS-12)
 Intrinsic Remediation TS
 King Salmon Airport, Alaska



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GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: ESMW-10 CONTRACTOR: AIR FORCE DATE SPUD: 9/21/94
 CLIENT: AFCEE RIG TYPE: CME 55 DATE CMPL.: 9/21/94
 JOB NO.: 722450.11 DRLG METHOD: HOLLOW STEM AUGER ELEVATION: 21.33 FEET ABOVE MLWL
 LOCATION: KING SALMON AFS BORING DIA.: 10 INCH OD TEMP: 40 F
 GEOLOGIST: KC DRLG FLUID: NONE WEATHER: CLEAR
 COMMENTS: BACKGROUND PID = 2.8 ppm

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample		Penet Res	PID(ppm)	WKSPE PID(ppm)	TOTAL BTX(ppm)	TPH (ppm)
					No.	Depth (ft)					
	1		Pt	6 inches of dark brown PEAT. Saturated at 6".				14.2	14.2		
				Grey, fine- to med.-grained SAND at 0.5 feet bgs.							
				Strong hydrocarbon odor							
				2 inch brown PEAT layer with sand at 3 feet bgs.		0-5		14.2			
	5		SP								
				SAA. Increasing sand grain size at 7 feet bgs.		5-10		2.8			
	10		GW	Gravelly, silty, pebbly COBBLES with sand.				2.8	2.6		
			SW	Brown, fine- to coarse-grained SAND.		10-12					
				Coarseness increases with depth.		12-14		2.8			
	15			Bottom of hole at 14 feet bgs.							
	20										
	25										
	30										
	35										

GEOLOGIC BORING LOG

Upper Naknek Site (SS-12)
 Intrinsic Remediation TS
 King Salmon Airport, Alaska



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NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB




Water level drilled

GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: ESMW-11A CONTRACTOR: AIR FORCE DATE SPUD: 9/19/94
 CLIENT: AFCEE RIG TYPE: HAND DATE CMPL.: 9/19/94
 JOB NO.: 722450.11 DRLG METHOD: HOLLOW STEM AUGER ELEVATION: 20.52 FEET ABOVE M.S.L.
 LOCATION: KING SALMON AFS BORING DIA.: 3 INCHES TEMP: 35 F
 GEOLOGIST: KC DRLG FLUID: NONE WEATHER: CLEAR AND COOL
 COMMENTS:

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample		Penet Res	PID(ppm)	WWSPE PID(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
					No.	Depth (ft)					
	1		Pt	Brown PEAT. Saturated at 6 inches bgs.							
				Frozen ground at 3 feet bgs.							
				Bottom of hole at 3 feet bgs.							
	5										
	10										
	15										
	20										
	25										
	30										
	35										

NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB



Water level drilled

GEOLOGIC BORING LOG

Upper Naknek Site (SS-12)
 Intrinsic Remediation TS
 King Salmon Airport, Alaska



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GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: ESMW-12A CONTRACTOR: AIR FORCE DATE SPUD: 9/19/94
CLIENT: AFCEE RIG TYPE: HAND DATE CMPL.: 9/19/94
JOB NO.: 722450.11 DRLG METHOD: HOLLOW STEM AUGER ELEVATION: 23.46 FEET ABOVE MLWL
LOCATION: KING SALMON AFS BORING DIA.: 3 INCHES TEMP: 50 F
GEOLOGIST: KC DRLG FLUID: NONE WEATHER: CLEAR, WINDY
COMMENTS:

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample		Penet Res	PID(ppm)	WKSPCE PID(ppm)	TOTAL BTX(ppm)	TPH (ppm)
					No.	Depth (ft)					
	1		Pt	PEAT, saturated at 3"							
			SW	Brown, silty SAND to sandy SILT. Turning grey at 4 feet bgs. Some clay present.							
	5			Bottom of hole at 4.5 feet bgs.							
	10										
	15										
	20										
	25										
	30										
	35										

NOTES

bgs - Below Ground Surface
GS - Ground Surface
TOC - Top of Casing
NS - Not Sampled
SAA - Same As Above

SAMPLE TYPE

D - DRIVE
C - CORE
G - GRAB



Water level drilled

GEOLOGIC BORING LOG

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska



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GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: ESMW-13A CONTRACTOR: AIR FORCE DATE SPUD: 9/22/94
 CLIENT: AFCEE RIG TYPE: CME 55 DATE CMPL.: 9/22/94
 JOB NO.: 722450.11 DRLG METHOD: HOLLOW STEM AUGER ELEVATION: 21.19 FEET ABOVE MSL
 LOCATION: KING SALMON AFS BORING DIA.: 10 INCH OD TEMP: 45 F
 GEOLOGIST: KC DRLG FLUID: NONE WEATHER: RAIN
 COMMENTS: NO PID MEASUREMENTS TAKEN DUE TO EXCESSIVE MOISTURE

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample		Penet Res	PID(ppm)	WKSPCE PID(ppm)	TOTAL BTX(ppm)	TPH (ppm)
					No.	Depth (ft)					
	1		Pt	Dark brown PEAT.							
				Brown, fine- to medium-grained SAND. Some clay. Increasing coarseness with depth.		0-5					
	5		SP	6 inch grey clay lens at 4 feet bgs SAA turning grey with 1 inch clay lenses spaced 3 inches apart. Saturated at 4.5 feet bgs.							
				SAA turning brown at 7 feet bgs.		5-10					
				SAA turning grey at 8.5 feet bgs.							
	10		GW	Grey, silty, sandy GRAVEL.							
			CH	Grey, clayey SILT to silty CLAY with gravel. High plasticity. Some brown sand lenses present.		10-15					
	15			Bottom of hole at 15 feet bgs.							
	20										
	25										
	30										
	35										


CONTINUOUS CORE

NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB

 Water level drilled

GEOLOGIC BORING LOG

Upper Naknek Site (SS-12)
 Intrinsic Remediation TS
 King Salmon Airport, Alaska



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GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: ESMW-14A CONTRACTOR: AIR FORCE DATE SPUD: 9/22/94
 CLIENT: AFCEE RIG TYPE: CME 55 DATE CMPL: 9/22/94
 JOB NO.: 722450.11 DRLG METHOD: HOLLOW STEM AUGER ELEVATION: 22.17 FEET ABOVE MLWL
 LOCATION: KING SALMON AFS BORING DIA.: 10 INCH OD TEMP: 45 F
 GEOLOGIST: KC DRLG FLUID: NONE WEATHER: RAIN
 COMMENTS: NO PID MEASUREMENTS TAKEN DUE TO EXCESSIVE MOISTURE

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample		Penet Res	PID(ppm)	WKSPCE PID(ppm)	TOTAL BTX(ppm)	TPH (ppm)
					No.	Depth (ft)					
	1		Pt	Brown, sandy PEAT. Moist.							
			SP	Brown, fine- to medium-grained silty SAND. Some coarse sand present.		0-4					
				SAA turning reddish-brown at 3 feet bgs. 6 inch clay lens at 3.5 feet bgs. Saturated.							
	5										
				SAA with increasing coarseness.		4-9					
	10										
			GW			9-14					
	15			Sandy, silty GRAVEL.							
				Bottom of hole at 14 feet bgs.							
	20										
	25										
	30										
	35										

NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB



Water level drilled

GEOLOGIC BORING LOG

Upper Naknek Site (SS-12)
 Intrinsic Remediation TS
 King Salmon Airport, Alaska



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GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: ESMW-15B CONTRACTOR: AIR FORCE DATE SPUD: 9/21/94
 CLIENT: AFCEE RIG TYPE: CME 55 DATE CMPL.: 9/21/94
 JOB NO.: 722450.11 DRLG METHOD: HOLLOW STEM AUGER ELEVATION: 36.30 FEET ABOVE MLW
 LOCATION: KING SALMON AFS BORING DIA.: 10 INCH OD TEMP: 45 F
 GEOLOGIST: KC DRLG FLUID: NONE WEATHER: OVERCAST
 COMMENTS: BACKGROUND PID = 2.8 ppm


Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	WKSPCE PID(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1			No Sample. FILL.		0-5	CONTINUOUS CORE					
	5		SM	Brown, sandy SILT to silty SAND with organics. Wood fragments. Dry. Most likely FILL.		5-10			2.8			
	10			SAA becoming wet at 9.8 feet bgs.		10-15			2.8			
	15		SP	Grey, fine- to medium-grained SAND. Saturated at 14 feet bgs.		15-20			2.8			
				SAA turning greyish-brown at 17 feet bgs.								
	20		MH			20-25	CONTINUOUS CORE		2.8			
				Grey, pebbly SILT with sand.								
			MH	Grey, sandy SILT with clay. Confining layer.								
	25			Bottom of hole at 25 feet bgs.								
	30											
	35											

NOTES

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 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB

 Water level drilled

GEOLOGIC BORING LOG

Upper Naknek Site (SS-12)
 Intrinsic Remediation TS
 King Salmon Airport, Alaska

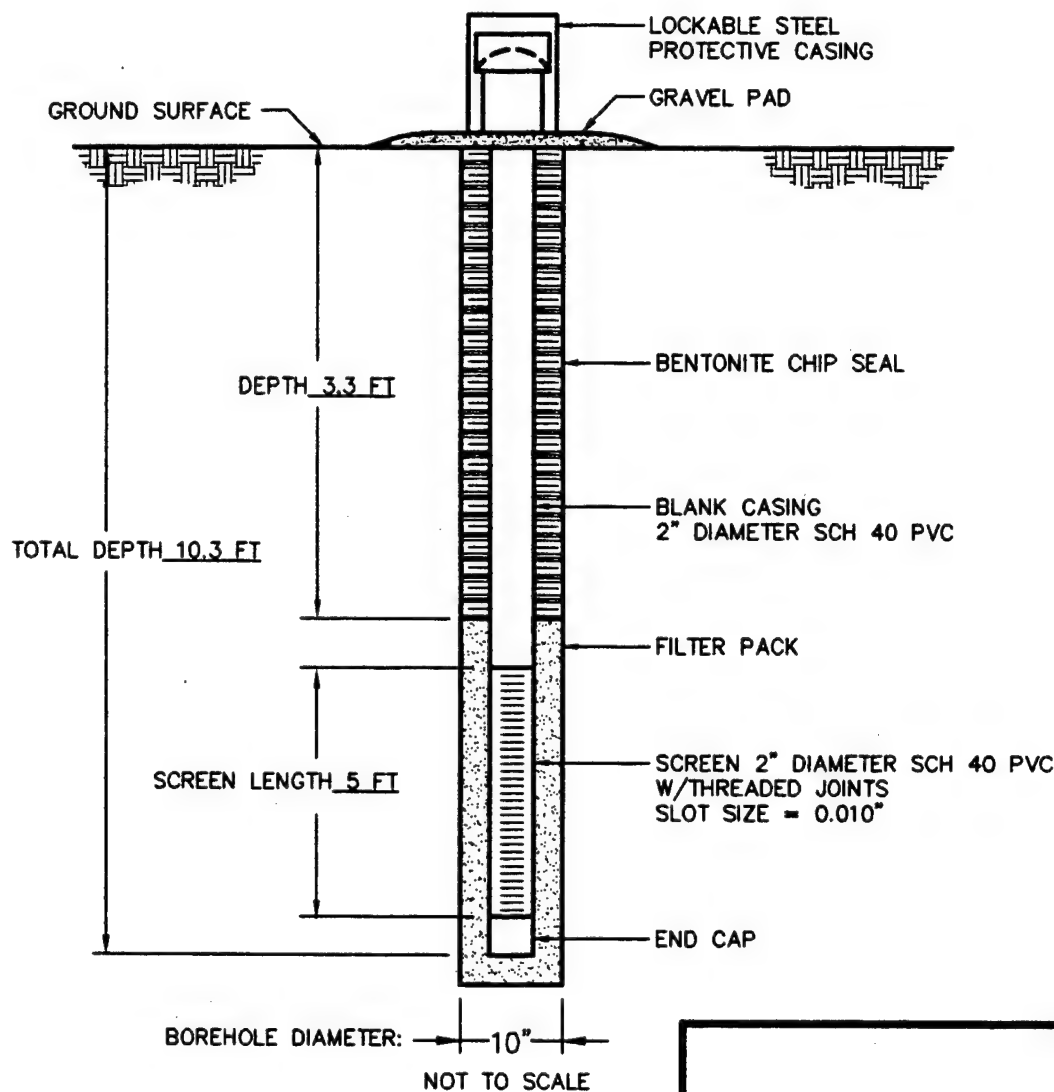


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MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION WELL NUMBER ESMW -8A
JOB NUMBER 722450.11 INSTALLATION DATE 9/20/94 LOCATION SS-12
DATUM ELEVATION 32.29 FEET ABOVE MLWL GROUND SURFACE ELEVATION 29.14 FT
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 10 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 9.31 FEET
BELOW DATUM.
TOTAL WELL DEPTH 12.81 FEET
BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska

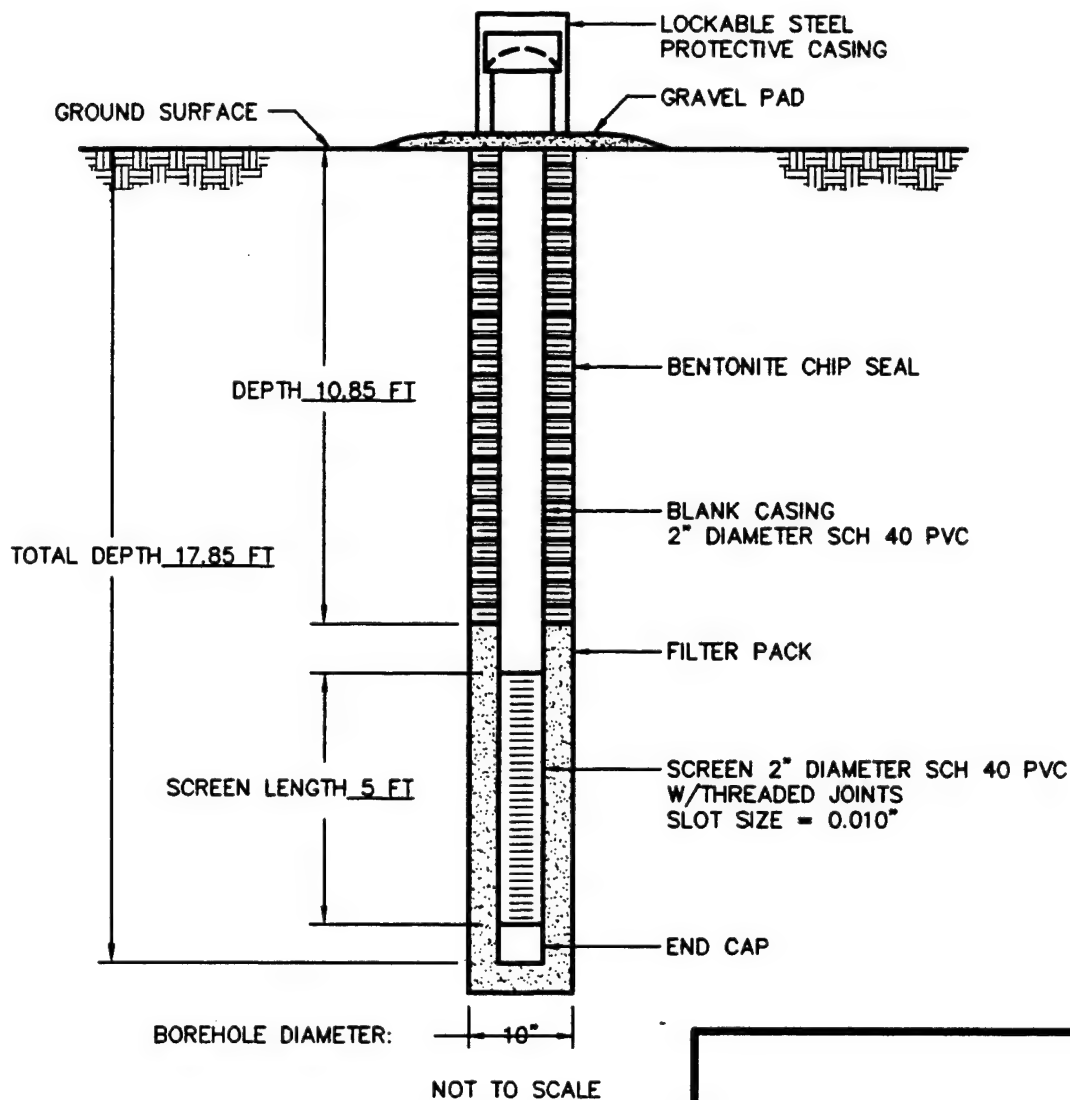


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MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION WELL NUMBER ESMW -8B
JOB NUMBER 722450.11 INSTALLATION DATE 9/19/94 LOCATION SS-12
DATUM ELEVATION 32.19 FEET ABOVE MLWL GROUND SURFACE ELEVATION 29.14 FT
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 10 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 9.25 FEET
BELOW DATUM.
TOTAL WELL DEPTH 21.71 FEET
BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska

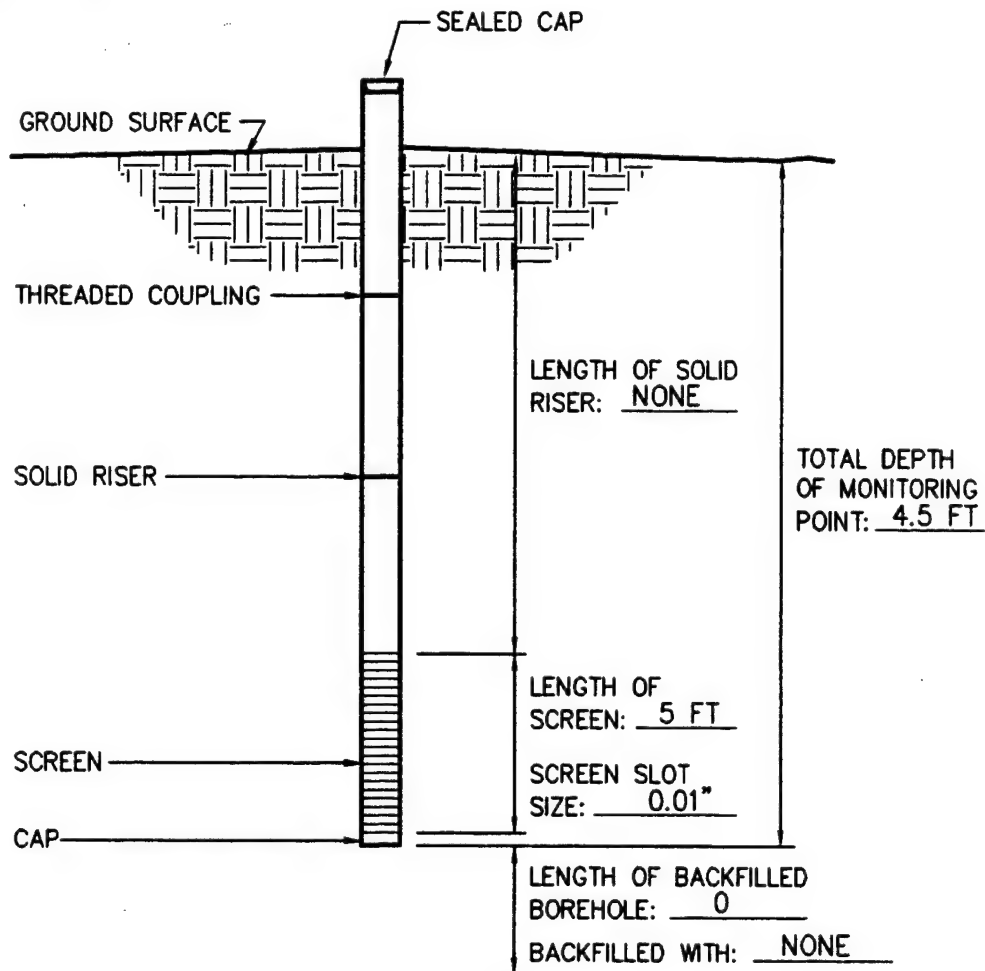


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MONITORING POINT INSTALLATION RECORD

JOB NAME KING SALMON AFS MONITORING POINT NUMBER ESMW-9A
JOB NUMBER 722450.11 INSTALLATION DATE 9/19/94 LOCATION SS-12
DATUM ELEVATION 25.5 FT ABOVE MLWL GROUND SURFACE ELEVATION 21.60 FT
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01"
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 3 INCH OD
POINT INSTALLATION CONTRACTOR AIR FORCE ES REPRESENTATIVE KC



NOT TO SCALE

STABILIZED WATER LEVEL 0.5 FT FEET
BELOW DATUM.

TOTAL MONITORING POINT DEPTH 4.5 FEET
BELOW DATUM.

MONITORING POINT INSTALLATION RECORD

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska

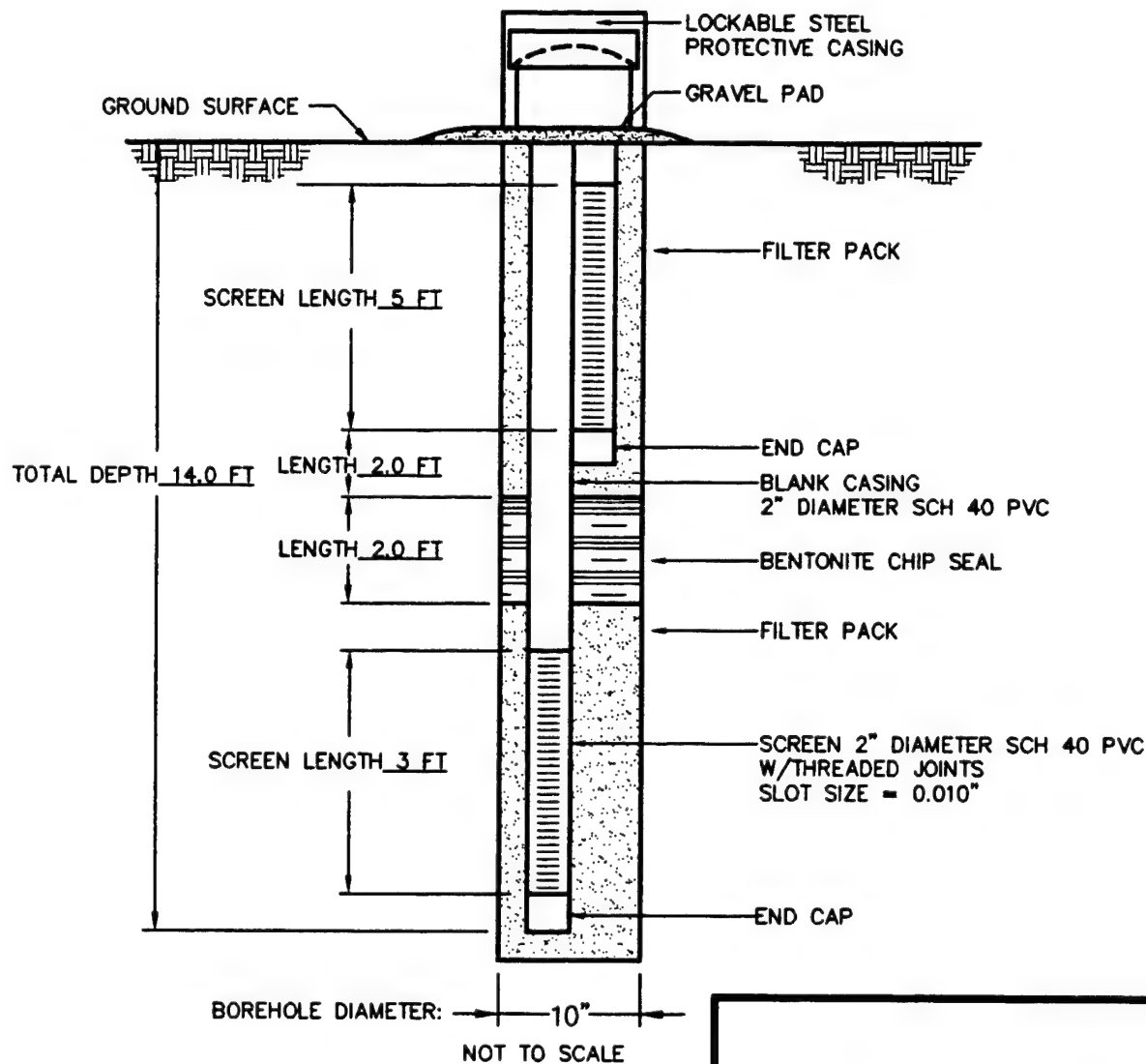


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ENGINEERING SCIENCE, INC.**

Denver, Colorado

MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION WELL NUMBER ESMW -10A/10B
 JOB NUMBER 722450.11 INSTALLATION DATE 9/22/94 LOCATION SS-12
 DATUM ELEVATION 30.82/ 24.18 FEET ABOVE MLWL GROUND SURFACE ELEVATION 36.30 FT
 DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
 SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01 "
 RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 10 INCH OD
 GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND ES REPRESENTATIVE KC
 DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR AIR FORCE



10A STABILIZED WATER LEVEL 3.11 FEET
 BELOW DATUM.
 TOTAL WELL DEPTH 10.24 FEET
 BELOW DATUM.

10B STABILIZED WATER LEVEL 2.95 FEET
 BELOW DATUM.
 TOTAL WELL DEPTH 17.55 FEET
 BELOW DATUM.
 MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

Upper Naknek Site (SS-12)
 Intrinsic Remediation TS
 King Salmon Airport, Alaska

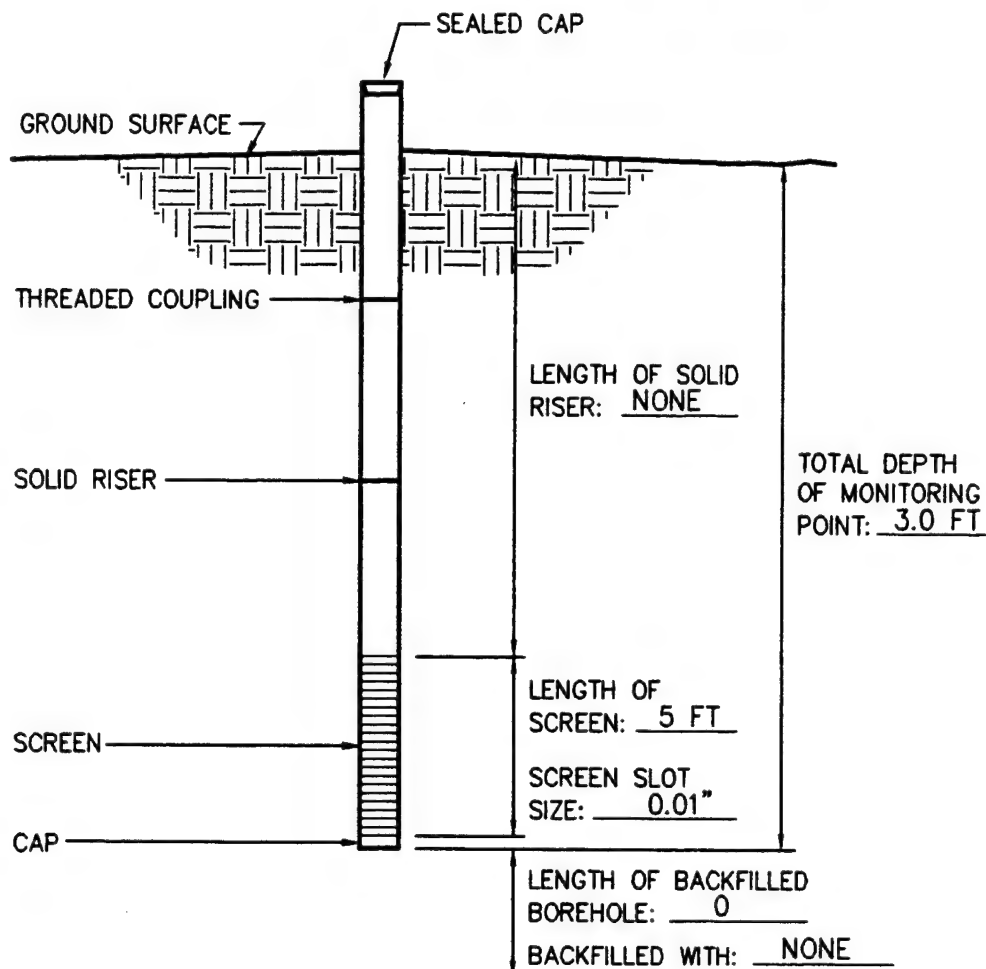


**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

MONITORING POINT INSTALLATION RECORD

JOB NAME KING SALMON AFS MONITORING POINT NUMBER ESMW-11A
JOB NUMBER 722450.11 INSTALLATION DATE 9/19/94 LOCATION SS-12
DATUM ELEVATION 23.53 FT ABOVE MLWL GROUND SURFACE ELEVATION 20.52 FT
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01"
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 3 INCH OD
POINT INSTALLATION CONTRACTOR AIR FORCE ES REPRESENTATIVE KC



(NOT TO SCALE)

STABILIZED WATER LEVEL 0.5 FT FEET
BELOW DATUM.

TOTAL MONITORING POINT DEPTH 3.0 FEET
BELOW DATUM.

MONITORING POINT INSTALLATION RECORD

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska

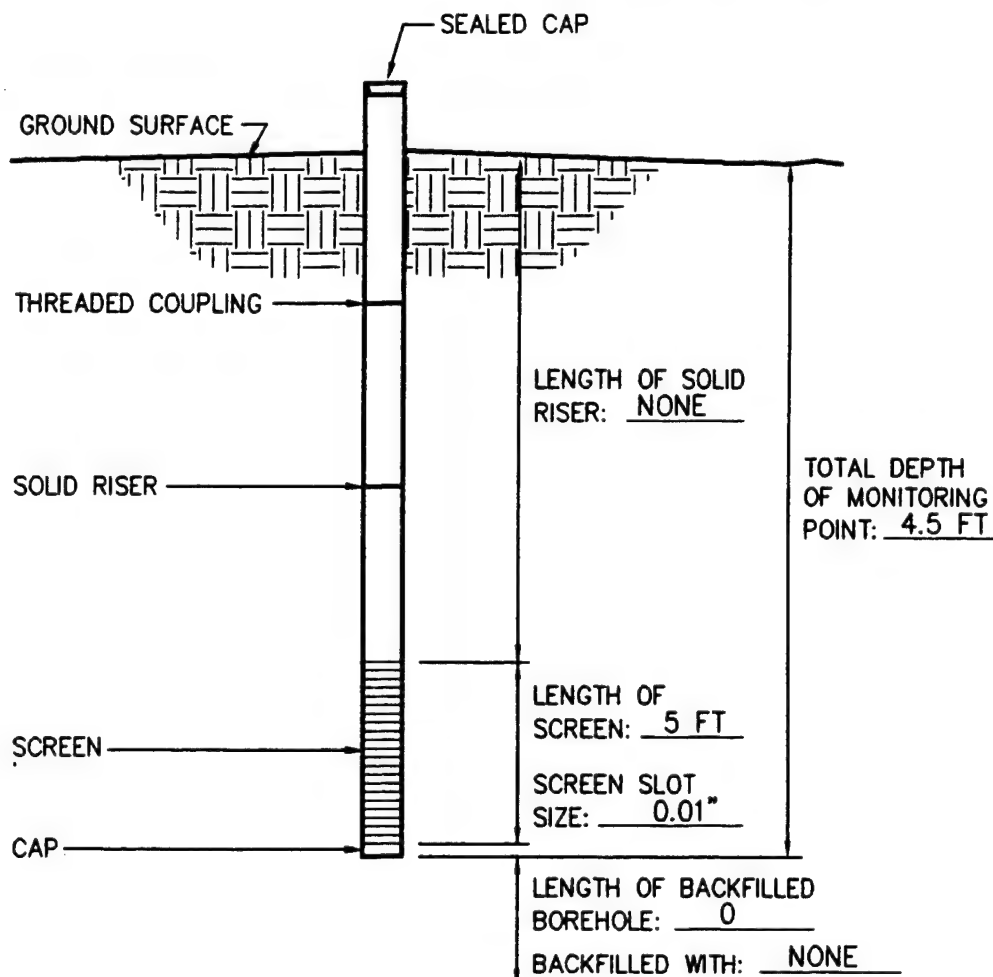


**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

MONITORING POINT INSTALLATION RECORD

JOB NAME KING SALMON AFS MONITORING POINT NUMBER ESMW-12A
JOB NUMBER 722450.11 INSTALLATION DATE 9/19/94 LOCATION SS-12
DATUM ELEVATION 23.48 FT ABOVE MLWL GROUND SURFACE ELEVATION _____
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01"
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 3 INCH OD
POINT INSTALLATION CONTRACTOR AIR FORCE ES REPRESENTATIVE KC



NOT TO SCALE

STABILIZED WATER LEVEL 0.5 FT FEET
BELOW DATUM.

TOTAL MONITORING POINT DEPTH 4.5 FEET
BELOW DATUM.

MONITORING POINT INSTALLATION RECORD

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska

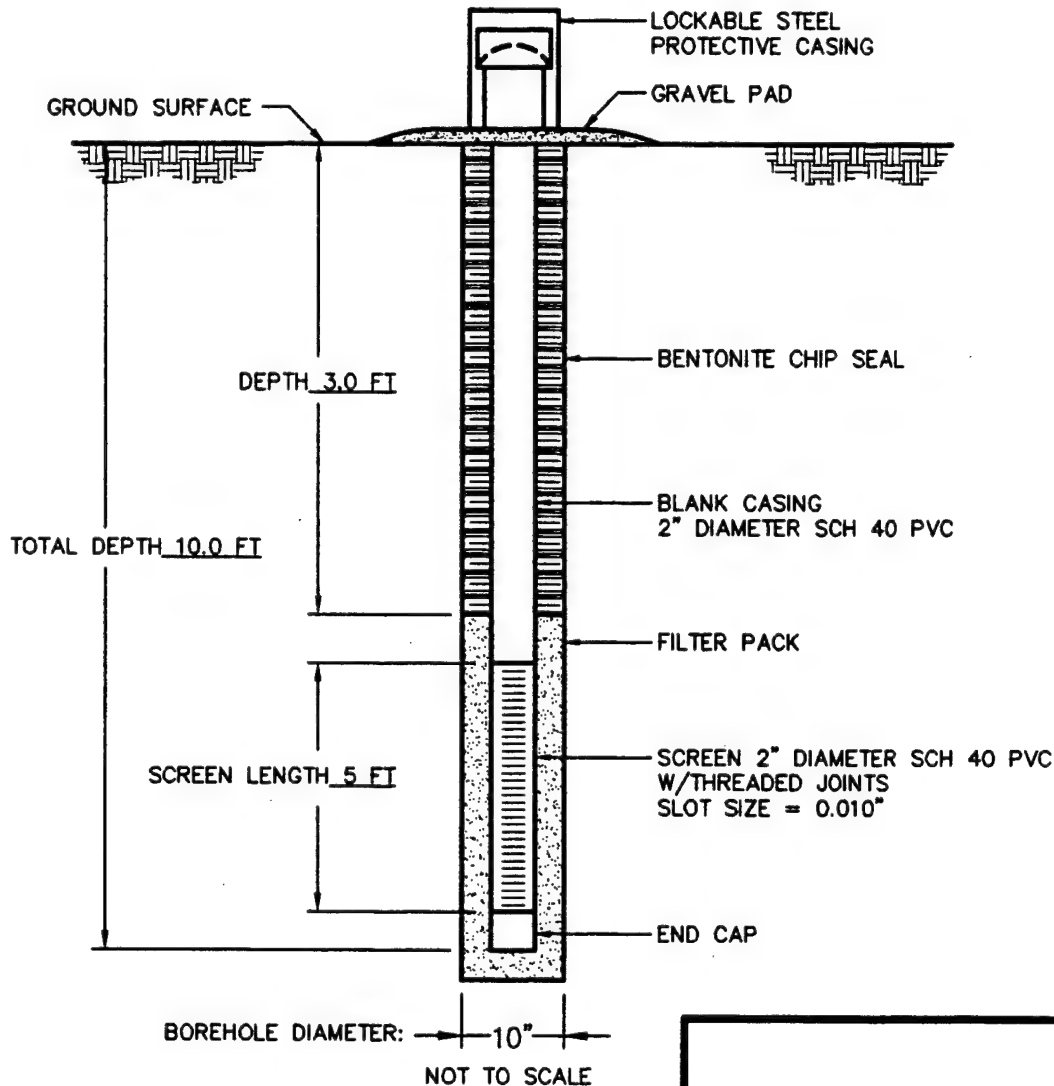


**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION WELL NUMBER ESMW -13A
JOB NUMBER 722450.11 INSTALLATION DATE 9/22/94 LOCATION SS-12
DATUM ELEVATION 24.02 FEET ABOVE MLWL GROUND SURFACE ELEVATION 21.29 FT
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 10 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 4.41 FEET
BELOW DATUM.
TOTAL WELL DEPTH 12.56 FEET
BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska

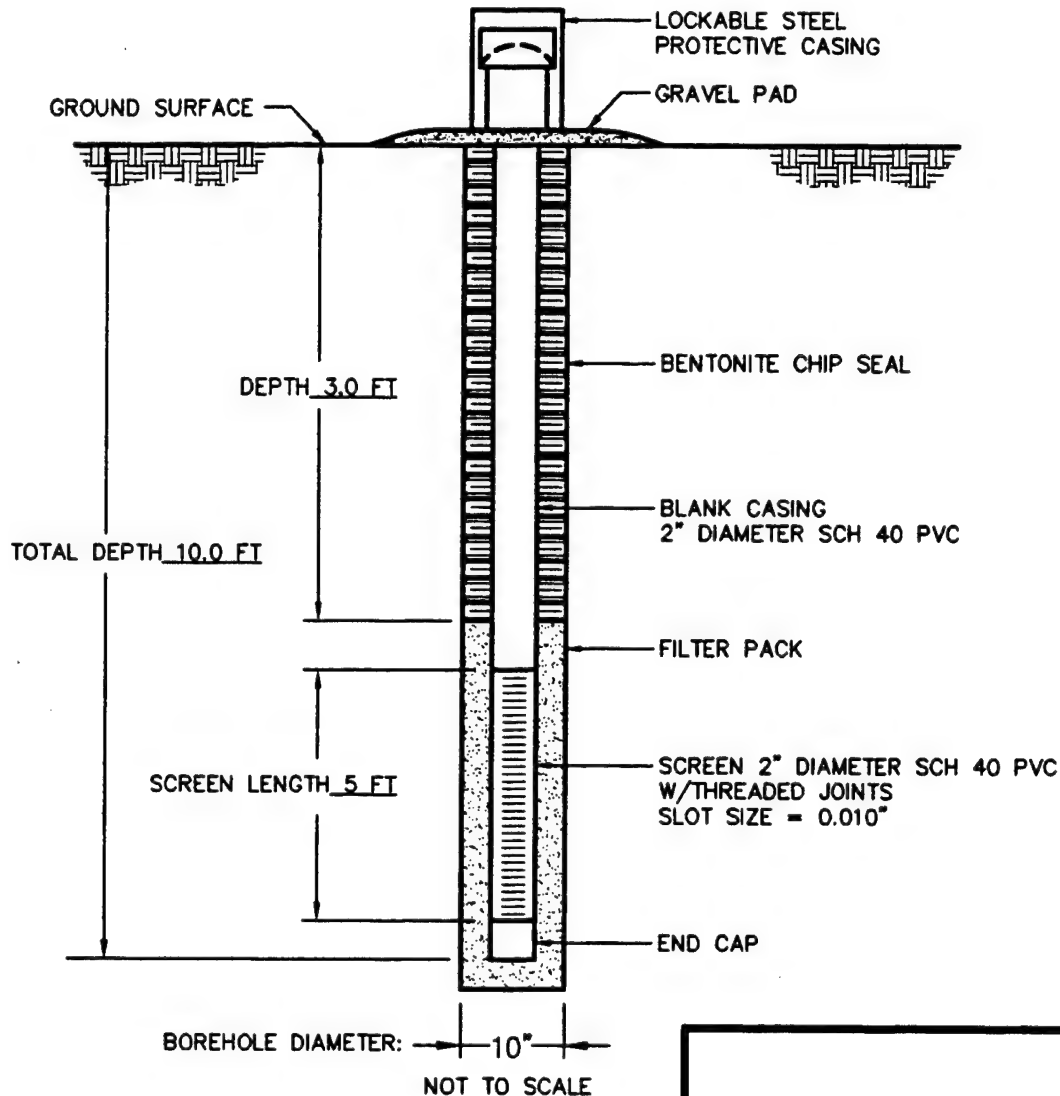


**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION WELL NUMBER ESMW -14A
JOB NUMBER 722450.11 INSTALLATION DATE 9/220/94 LOCATION SS-12
DATUM ELEVATION 25.04 FEET ABOVE MLWL GROUND SURFACE ELEVATION 22.17 FT
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 10 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 6.51 FEET
BELOW DATUM.
TOTAL WELL DEPTH 12.73 FEET
BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska

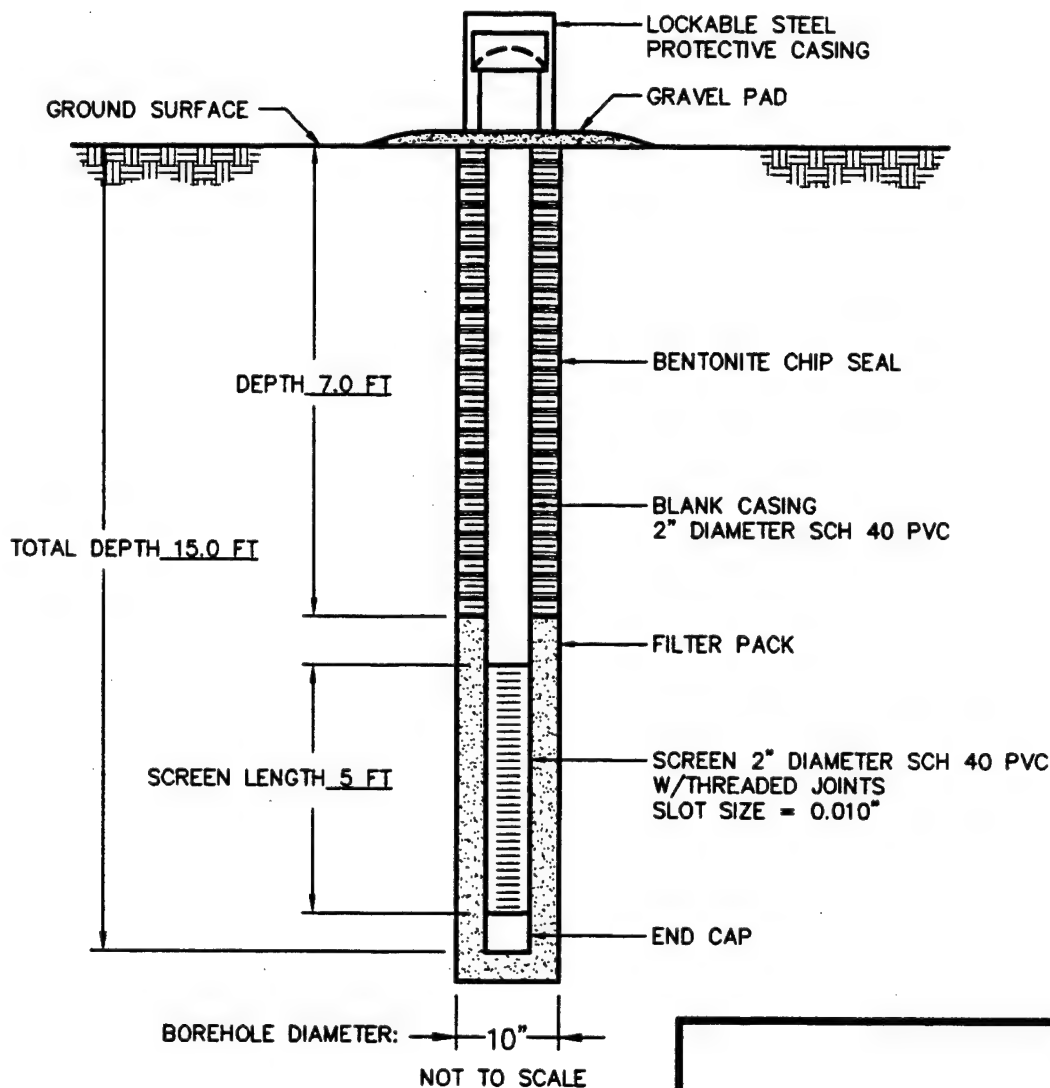


**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION WELL NUMBER ESMW -15A
JOB NUMBER 722450.11 INSTALLATION DATE 9/22/94 LOCATION SS-12
DATUM ELEVATION 39.15 FEET ABOVE MLWL GROUND SURFACE ELEVATION 36.30 FT
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 10 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 14.27 FEET
BELOW DATUM.
TOTAL WELL DEPTH 17.77 FEET
BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska

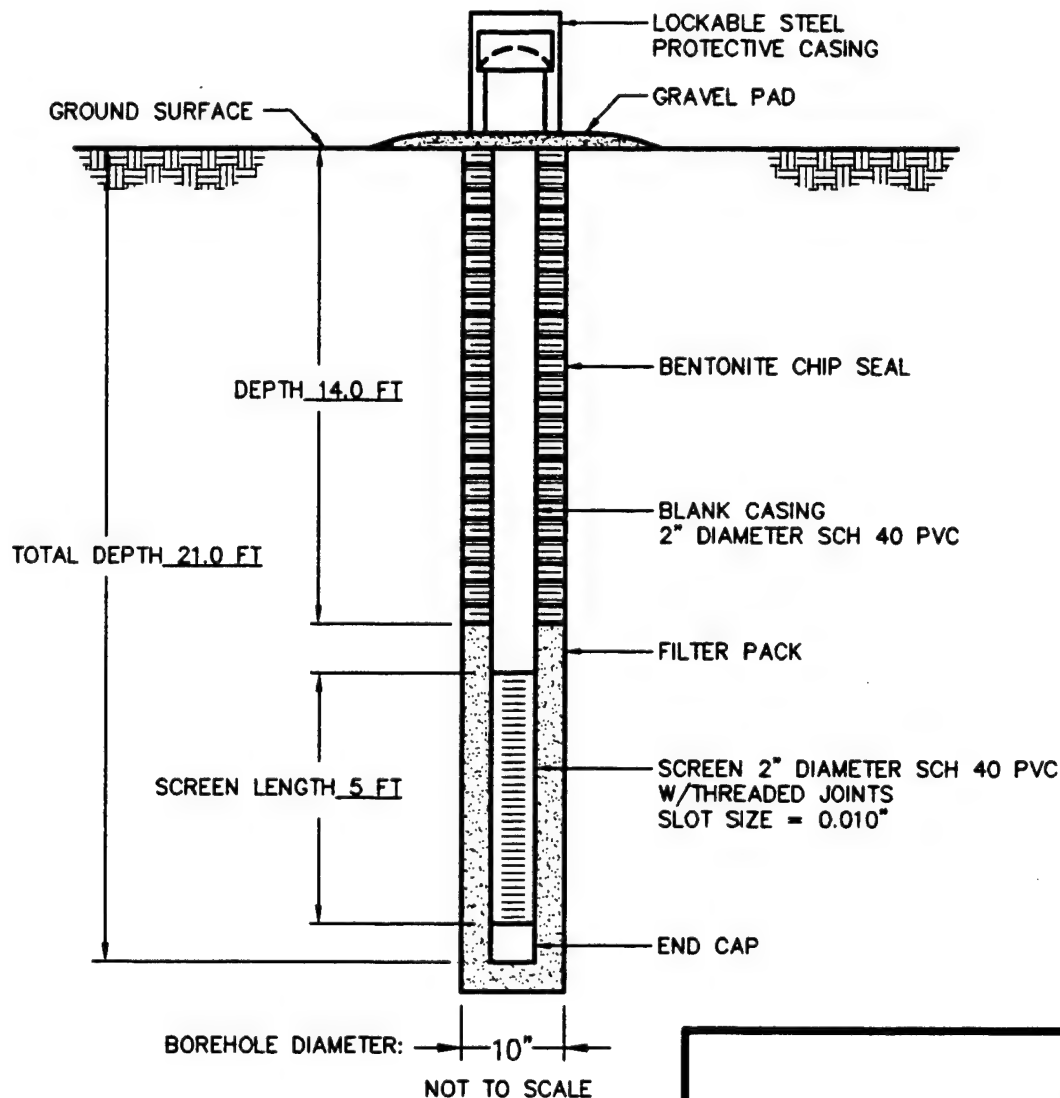


**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIR FORCE STATION WELL NUMBER ESMW -15B
JOB NUMBER 722450.11 INSTALLATION DATE 9/22/94 LOCATION SS-12
DATUM ELEVATION 39.00 FEET ABOVE MLWL GROUND SURFACE ELEVATION 36.30 FT
DATUM FOR WATER LEVEL MEASUREMENT TOP OF PVC CASING
SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01 "
RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 10 INCH OD
GRANULAR BACKFILL MATERIAL 20-40 COLORADO SAND ES REPRESENTATIVE KC
DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR AIR FORCE



STABILIZED WATER LEVEL 14.44 FEET
BELOW DATUM.
TOTAL WELL DEPTH 26.21 FEET
BELOW DATUM.
MEASURED ON WATER LEVEL PROBE

MONITORING WELL INSTALLATION RECORD

Upper Naknek Site (SS-12)
Intrinsic Remediation TS
King Salmon Airport, Alaska



**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

508
compny
PARSONS ENGINEERING-SCIENCE
projno
722450.11
client
AFCEE
locsit
KING SALMON, ALASKA
tstdat
9-26-4
tstwel

obswel

508

slugt1

3.1854

0.1667

0.833

slugt2

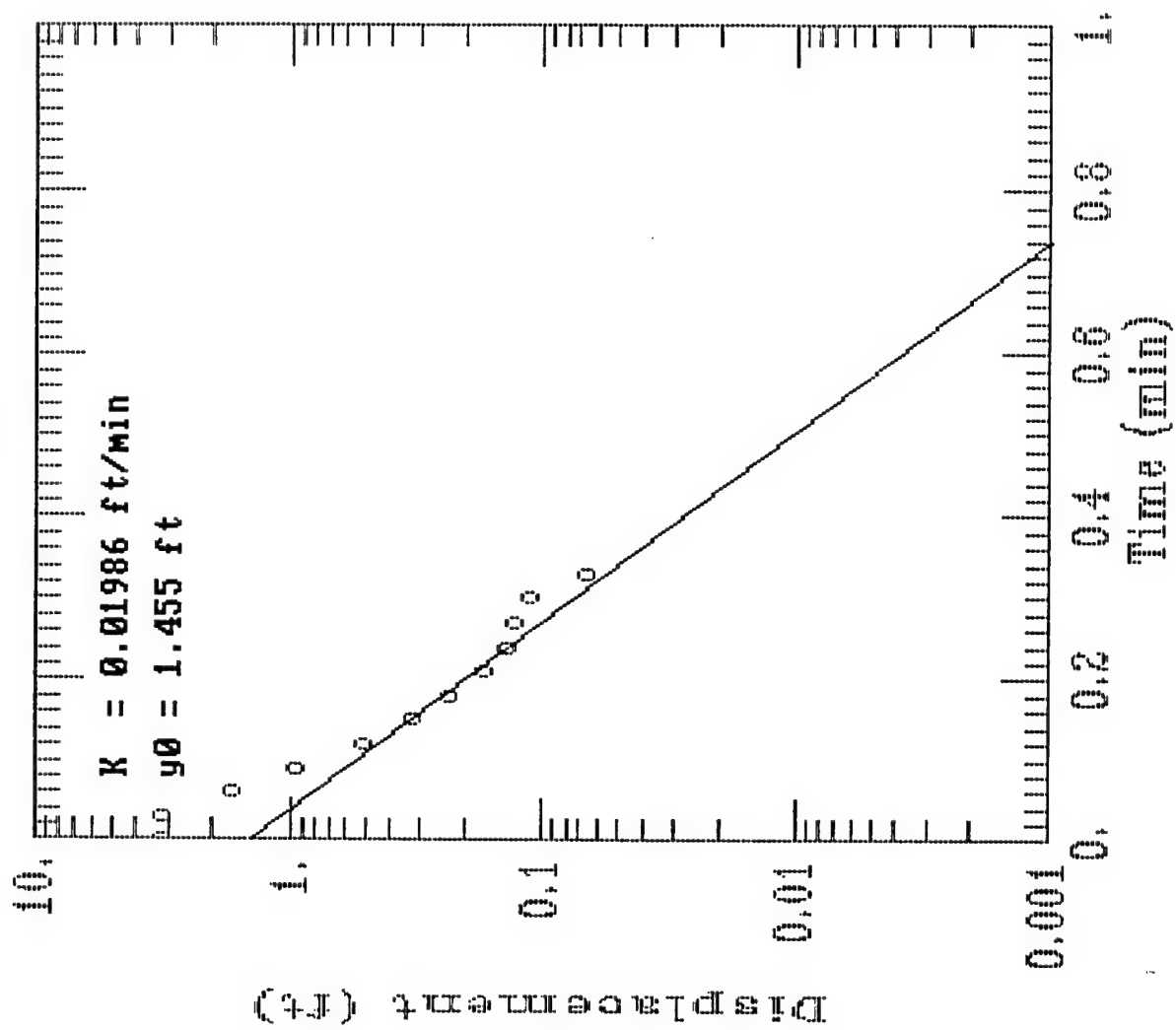
15

10

8.2465

tsdata

0.03	3.1854	1
0.06	1.6899	1
0.09	0.9379	1
0.12	0.5154	1
0.15	0.3295	1
0.18	0.2281	1
0.21	0.169	1
0.24	0.1352	1
0.27	0.1267	1
0.3	0.1098	1
0.33	0.0676	1



508

compny

PARSONS ENGINEERING SCIENCE

projno

722450.11

client

AFCEE

locsit

KING SALMON, ALASKA

tstdat

9-26-94

obswel

508

slugt1

2.7798

0.166

0.833

slugt2

15

10

8.3479

tsdata

0.03	2.7798	1
------	--------	---

0.06	1.4786	1
------	--------	---

0.09	0.8111	1
------	--------	---

0.12	0.4478	1
------	--------	---

0.15	0.2788	1
------	--------	---

0.18	0.1859	1
------	--------	---

0.21	0.1352	1
------	--------	---

0.24	0.1014	1
------	--------	---

0.27	0.0845	1
------	--------	---

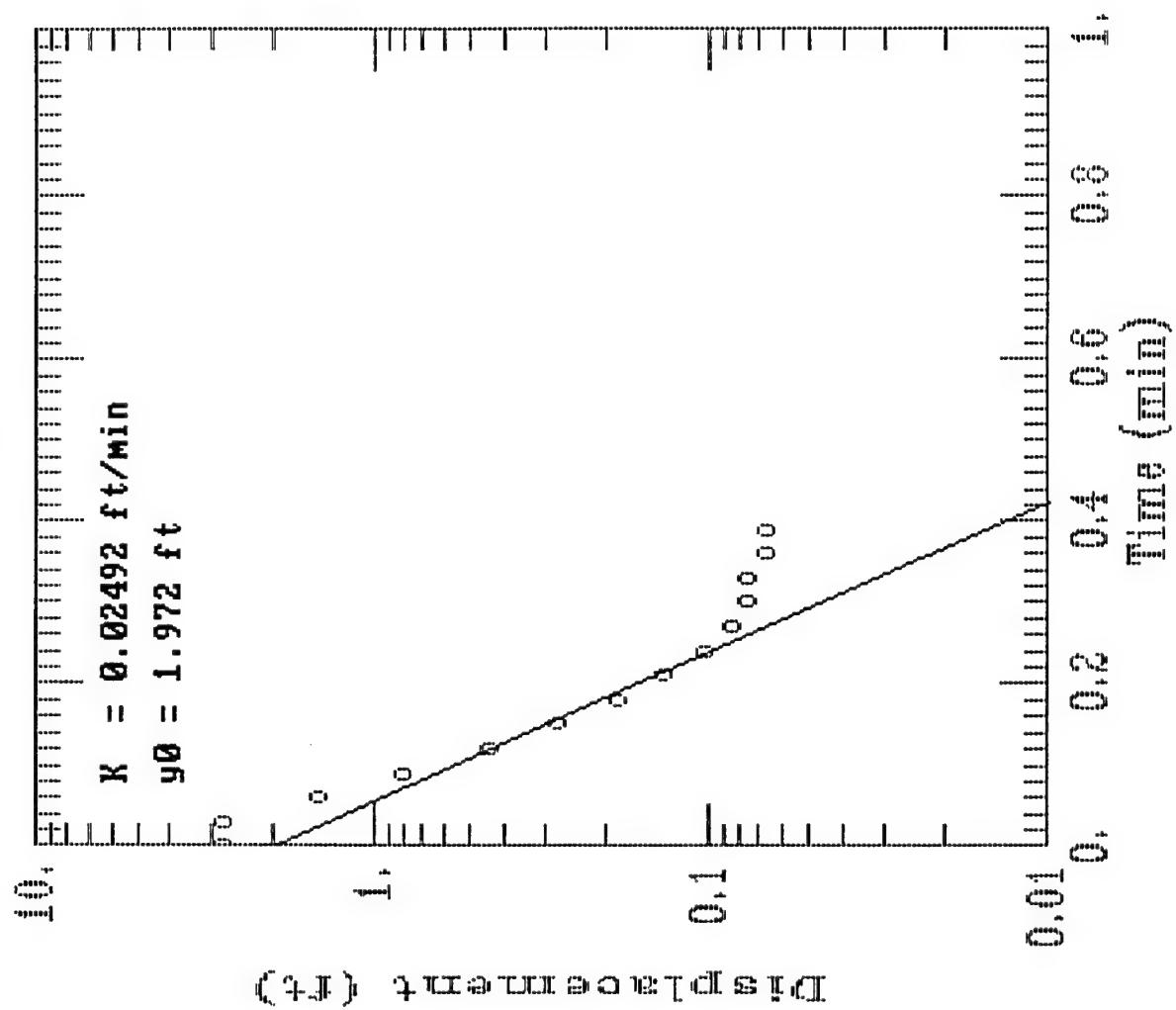
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0.33	0.0761	1
------	--------	---

0.36	0.0676	1
------	--------	---

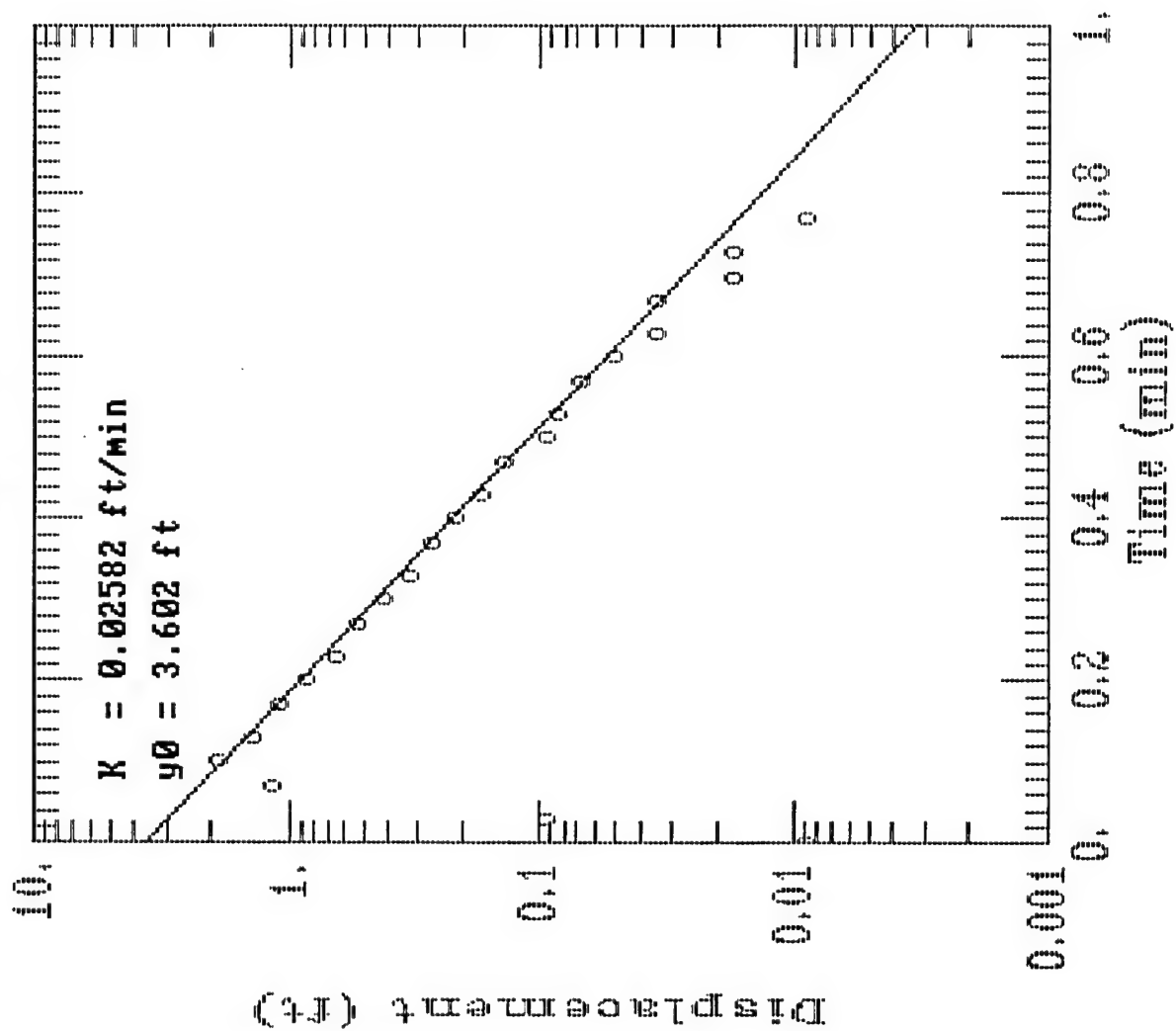
0.39	0.0676	1
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508



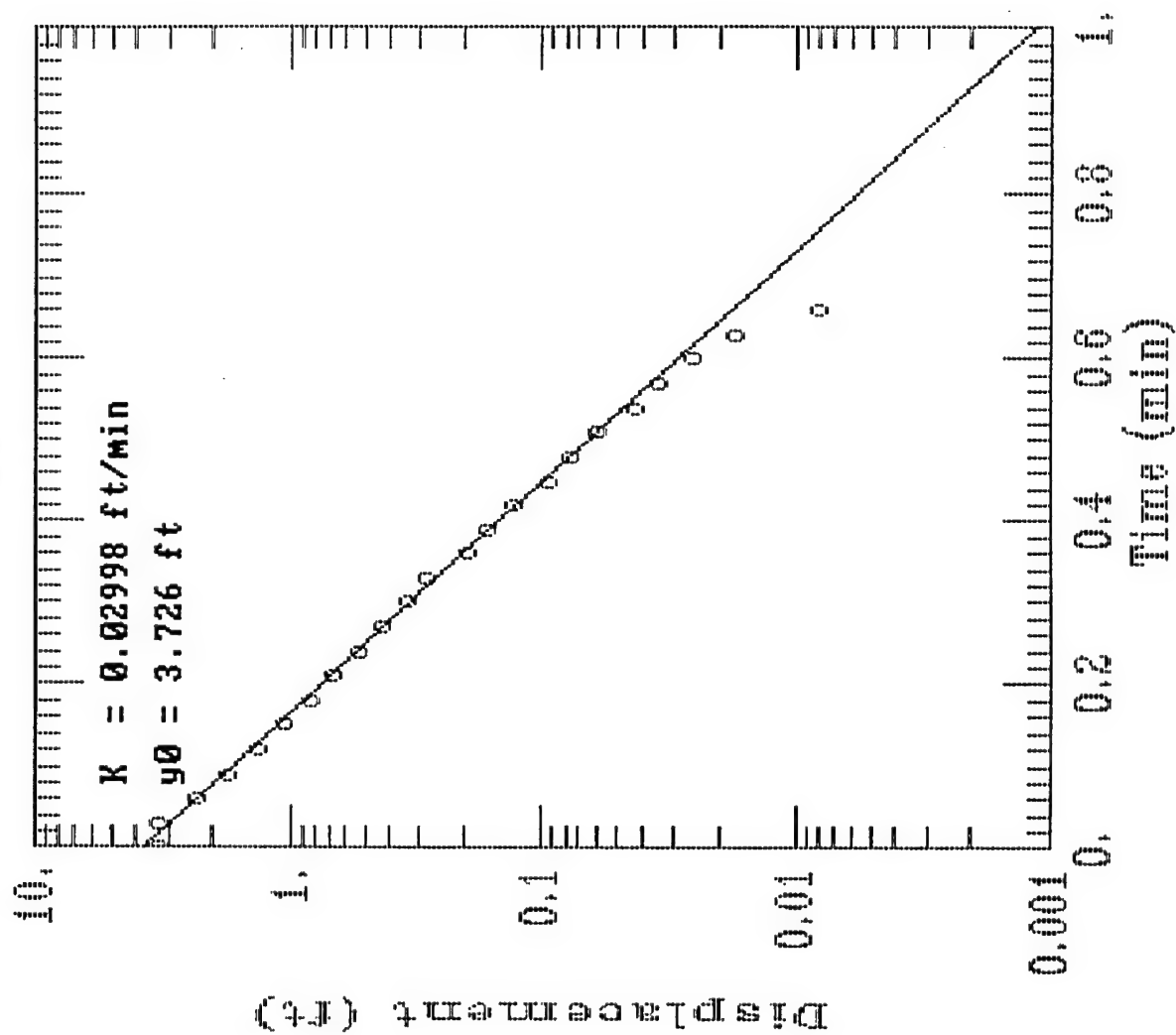
ESMW-8B
compny
ENGINEERING SCIENCE
projno
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KING SALMON, ALASKA
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ESMW-8B
slugt1
0.009
0.166
0.833
slugt2
15
5
12.564
tsdata
0.03 0.093 1
0.07 1.183 1
0.1 1.868 1
0.13 1.403 1
0.17 1.082 1
0.2 0.845 1
0.23 0.659 1
0.27 0.524 1
0.3 0.414 1
0.33 0.33 1
0.37 0.262 1
0.4 0.212 1
0.43 0.169 1
0.47 0.136 1
0.5 0.093 1
0.53 0.085 1
0.57 0.068 1
0.6 0.051 1
0.63 0.034 1
0.67 0.034 1
0.7 0.017 1
0.73 0.017 1
0.77 0.009 1

ESMW-8B



ESMW-8B
compny
ENGINEERING SCIENCE
projno
722450.11
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AFCEE
locsit
KING SALMON, ALASKA
slugt1
3.2441
0.166
0.833
slugt2
15
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12.589
tsdata
0.03 3.2441 1
0.06 2.332 1
0.09 1.766 1
0.12 1.36 1
0.15 1.065 1
0.18 0.836 1
0.21 0.667 1
0.24 0.524 1
0.27 0.422 1
0.3 0.338 1
0.33 0.279 1
0.36 0.194 1
0.39 0.161 1
0.42 0.127 1
0.45 0.093 1
0.48 0.076 1
0.51 0.059 1
0.54 0.042 1
0.57 0.034 1
0.6 0.025 1
0.63 0.017 1
0.66 0.008 1

ESMW-8B



APPENDIX B

LABORATORY ANALYTICAL DATA

MANTECH

Ref: 94-MW97/vg
94-LP97/vg

September 27, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
Post Office Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift *SA*

Dear Don:

Attached are the results of 26 samples from King Salmon submitted to ManTech as part of S.R. #SF-0-76. The samples were received on September 23, 1994 and analyzed September 26, 1994. The methods used for analysis were EPA Method 353.1, 120.1, and Water's capillary electrophoresis method N-601. Quality assurance measures performed on this set of samples included spikes, duplicates, known AQC samples and blanks.

If you have any questions concerning these results please feel free to contact us.

Sincerely,



Mark White

Lynda Pennington
Lynda Pennington

xc: R.L. Cosby
J.L. Seeley *jls*

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

Sample	mg/l $\text{NO}_2^- + \text{NO}_3^- (\text{N})$	Cond.	mg/l Cl^-	mg/l SO_4^{2-}
KSWP-1	<.05	174	15.2	<.5
KSWP-2	<.05	245	20.7	2.01
KSWP-3	.13	85	16.4	1.66
KSWP-3. Dup	----	----	16.5	1.56
ESMW-2A	2.69	195	2.98	6.38
ESMW-2A Dup	2.73	----	----	----
ESMW-2B	.11	141	3.36	3.44
ESMW-3A	.05	97	2.80	2.85
ESMW-3B	.55	106	3.71	3.56
ESMW-4A	.6	120	3.57	4.00
ESMW-4A Dup	----	----	3.63	3.98
ESMW-4B	.40	81	3.88	2.61
ESMW-4B Dup	.40	81	----	----
ESMW-6B	.23	109	3.50	3.53
KSMW-ES7A	2.82	188	4.51	5.26
KSMW-7B	<.05	133	3.35	1.30
ESMW-12A	<.05	64	3.77	<.5
KSMW-51	<.05	368	3.28	1.09
KSMW-88	<.05	200	7.57	4.88
KSMW-91	.13	86	2.92	3.33
KSMW-92	.92	134	3.49	3.13
KSMW-92 Dup	----	----	3.43	3.14
KSMW-93	.34	80	2.71	2.97
KSMW-94	<.05	86	2.10	0.85
KSMW-94 Dup	<.05	----	----	----
KSMW-95	.06	141	3.07	1.96
KSMW-95 Dup	----	141	----	----
KSMW-435	<.05	276	2.79	2.78
KSMW-460B	.55	233	2.90	6.91
KSMW-460B Dup	----	----	3.12	6.86
KSMW-462C	.14	97	2.36	1.80
KSMW-501	.07	112	3.74	4.18
KSMW-508	<.05	45	3.43	2.06
KSMW-508 Rep	<.05	44	3.49	2.05
Blanks	<.05	1	<.5	<.5
AQC	2.75	----	107	73.7
True Value	2.81	----	106	75.0
Spike Recovery	102%	----	97%	98%

MANTECH

Ref: 94-MW96/vg
94-LP95/vg

September 26, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
Post Office Box 1198
Ada, OK 74820

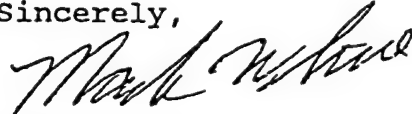
THRU: S.A. Vandegrift *SAV*

Dear Don:

Attached are the results of 11 samples from King Salmon submitted to ManTech as part of S.R. #RE-0-76. The samples were received on September 20, 1994 and analyzed immediately. The methods used for analysis were EPA Method 350.1, 120.1, and Water's capillary electrophoresis method N-601. Quality assurance measures performed on this set of samples included spikes, duplicates, known AQC samples and blanks.

If you have any questions concerning these results please feel free to contact us.

Sincerely,



Mark White



Lynda Pennington

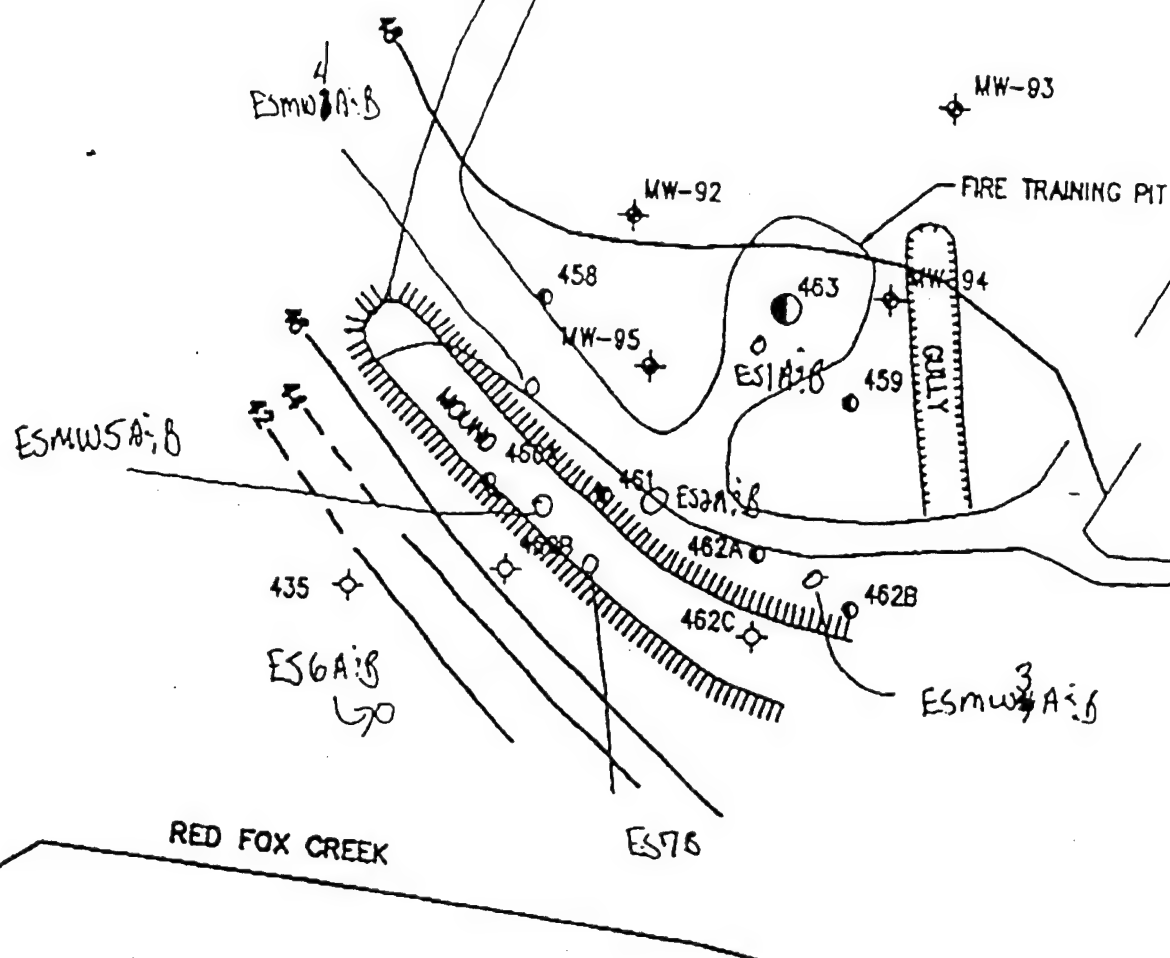
xc: R.L. Cosby
J.L. Seeley *jls*

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

<u>Sample</u>	<u>mg/l</u> <u>NO₂⁻ + NO₃⁻(N)</u>	<u>Cond.</u>	<u>mg/l</u> <u>Cl⁻</u>	<u>mg/l</u> <u>SO₄⁻²</u>
ESMW-1A	0.09	300	2.93	3.43
ESMW-1B	0.38	104	3.43	<.5
KSMW-50	No Sample Rec'd	48	1.94	<.5
KSMW-52	<.05	187	3.08	<.5
KSMW-53	0.09	108	6.12	<.5
KSMW-60	0.09	53	3.81	<.5
KSMW-60 Dup	----	----	3.84	<.5
KSMW-89	0.05	111	3.44	2.86
KSMW-90	0.07	90	3.72	2.61
KSMW-500	0.05	274	4.08	1.57
KSMW-506*	No Sample Rec'd	122	4.05	12.2
KSMW-506*	----	----	4.04	12.3
KSMW-509	0.07	No Sample Received		
Blanks	<.05	1	<.5	<.5
AQC	2.71	----	110	74.6
True Value	2.81	----	106	75.0
Spike Rec	100%	----	100%	101%

* Samples have identical labels

**LEGEND**

- MW-92
460
461
- MONITORING WELL (INSTALLED PRIOR TO FALL 1993)
- A-AQUIFER MONITORING WELL (INSTALLED FALL 1993)
- SOIL BORING
- 48
- A-AQUIFER GROUND WATER SURFACE
(FEET ABOVE MLLW)

**FIGURE 2.4**

**GROUND WATER ELEVATIONS
AT SITE FT01
(OCTOBER 1993)**

KING SALMON AIRPORT, AK EE/CA

ENGINEERING-SCIENCE, INC.

Denver, Colorado

SECTION 3

EMCON, 1994a

U:\45671\DRAWNGS\94DN0761, 08/26/94 at 10:52

King Salmon 4FB

Ground water Sam

Sample	Date	Temp. C°	Depth foc feet	Cond. mg/L	Total alkalinity mg/L	Ferrous Soluble Iron mg/L	Manganese mg/L	Dissolved oxygen mg/L	pH	Free chlorine mg/L	Redox mg/L	Phenols mg/L
KSMW-435	9-14-94	5.0	18.34	264	116	<0.05	0.5	2.0	7.1	10	214	
KSMW-94	9-14-94	9.0	11.54	82	36	<0.05	<0.1	6.9	6.4	17	207	
KSMW-93	9-14-94	6.1	11.32	76	24	<0.05	<0.1	6.6	6.1	40	220	
KSMW-92	9-14-94	5.0	16.54	118	45	<0.05	<0.1	3.0	6.1	44	219	
KSMW-95	9-14-94	5.9	12.48	145	58	1.2	0.4	0.7	6.6	32	55	0.2
KSMW-4608	9-15-94	7.2	14.46	219	89	<0.05	0.4	2.5	6.5	48	240	
KSMW-462C	9-15-94	6.8	5.40	94	41	<0.05	<0.1	1.4	6.3	90	282	0.1
KSMWES-7A	9-15-94	5.9	12.08	180	43	<0.05	0.2	9.0	6.3	36	266	
KSMWES-7B	9-15-94	5.0	11.60	128	55	<0.05	0.1	0.7	6.5	40	262	
KSMW-51	9-15-94	7.0	9.88	402	205	11.4	0.7	0.1	6.6	100	50	0.2
KSMW-501	9-16-94	5.2	12.9	109	18	<0.05	<0.1	3.6	5.7	40		
KSMW-88	9-16-94	5.2	12.5	200	80	3.2	0.5	1.2	6.2	112	92	
KSMW-500	9-16-94	5.8	17.0	354	172	30.	0.3	0.2	6.4	165	-25	0.2
KSMW-90	9-16-94	5.8	16.28	84	33	<0.05	<0.1	11.7	6.7	14	144	
KSMW-89	9-16-94	6.9	9.56	105	43	0.1	<0.1	0.3	6.2	34	143	
KSMW-52	9-17-94	8.3	3.52	210	93	5.9	0.3	0.5	6.4	60	-35	
KSMW-506	9-17-94	6.5	2.90	119	34	<0.05	<0.1	0.3	7.7	8	-260	
KSMW-509	9-17-94	7.2	6.9	40	12	<0.05	<0.1	4.8	5.7	32	183	
KSMW-60	9-17-94	7.1	7.5	52	15	<0.05	0.1	4.3	5.8	40	200	
KSMW-50	9-17-94	7.8	9.5	47	14	<0.05	<0.1	10.5	6.3	16	214	
KSMW-53	9-17-94	7.2	14.8	102	38	<0.05	<0.1	10.9	6.3	14	195	
KSMW-1A	9-17-94	6.7	13.8	287	132	2.5	0.9	0.9	6.5	140	63	0.3
ESMW-8A	9-22-94	8.0	9.36	503	256	32.	0.8	0.3	6.5	280	-17	
ESMW-8B	9-22-94	6.7	9.26	175	80	<0.05	<0.1	0.7	7.4	38	27	

King Salmon IFB

Ground water Samples

Sample Date	Temp. °C	Depth TOC feet	Cond.	Total Alkalinity mg/call	Formic Soluble Iron mg/l	Formic Soluble Manganese mg/l	Dissolved Oxygen mg/l	pH	Free Calcium mg/l	Redox phend's mg/l
KSMW-1B 9-17-94	5.4	13.88	99	21	<.05	<.01	2.1	6.9	10	202
KSMW-3A 9-19-94	6.7	14.26	90	38	<.05	0.1	2.7	6.6	—	288
KSMW-3B 9-19-94	5.9	14.82	108	44	<.05	<.01	1.0	6.5	—	284
KSMW-2A 9-19-94	8.2	15.62	185	67	<.05	—	4.4	6.5	—	288
KSMW-2B 9-19-94	7.8	15.58	136	58	<.05	—	0.4	6.4	—	265
KSWP-3 9-19-94	7.7	marsh surface	174	69	44	<.01	0.3	6.0	200	60 0.2
KSWP-2 9-19-94	9.8	11	286	140	15	0.2	2.5	6.9	60	-50
KSWP-1 9-19-94	8.7	11	190	96	8.0	0.1	1.0	6.4	80	37
KSMW-4A 9-20-94	6.8	15.50	116	47	<.05	<.01	7.0	6.2	401	280
KSMW-4B 9-20-94	6.9	15.48	76	9	<.05	<.01	7.5	7.0	12	271
KSMW-6B 9-20-94	7.3	7.76	102	40	<.05	<.01	4.0	6.4	24	297
KSMW-12A 9-20-94	8.0	3.62	86	16	7.2	<.01	0.8	6.1	106	180
KSMW-91 9-20-94	6.8	11.64	82	35	<.05	0.1	0.2	7.3	8	220
KSMW-50B 9-20-94	6.5	6.24	43	48	0.1	<.01	4.4	6.1	36	215
KSMW-5A 9-21-94	7.4	9.78	230	84	<.05	0.2	3.3	6.8	48	254
KSMW-5B 9-21-94	5.6	7.12	132	57	<.05	<.01	1.4	7.7	8	242
KSMW-10A 9-22-94	6.9	2.08	200	98	<.05	0.1	0.8	6.3	46	253
KSMW-10B 9-22-94	5.8	1.94	106	49	<.05	<.01	6.7	7.2	12	255
ESMW-15A 9-22-94	7.5	14.32	—	153	40	0.5	1.8	6.2	>300	—
ESMW-15B 9-22-94	7.5	14.42	—	136	0.2	0.3	0.2	7.0	42	—
well 507 9-22-94	7.8	4.26	—	68	0.2	<.01	1.6	6.4	48	—
ESMW-13A 9-23-94	4.0	4.5	—	119	20	<.01	0.1	6.5	176	—
ESMW-14A 9-23-94	4.5	6.5	—	34	0.2	<.01	0.7	6.5	94	—

King Salmon Airport

Volatile fatty acids analyzed by GC/MS.

all water samples contained some components of phenol/aliphatic/aromatic fatty acids. Their presence indicates that intrinsic remediation has or is occurring as the result of abiotic or biotic processes.

Water sample ESMW-8A had an organic functional group relative ratio as follows;

<u>Functional Group</u>	<u>Percent of Total</u>
aliphatic	72.3
phenols	4.6
aromatic	7.8
alkenyl/cycloalkylcarboxic	11.7
dienic/cycloalkenylcarboxic	3.6
Cyclodienylcarboxylic	0.0

Pat Campbell 11/1/94

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

ELEMENT	7196			7197			7198			7199		
	VALUE	STDV +/-		VALUE	STDV +/-		VALUE	STDV +/-		VALUE	STDV +/-	LOD
Na-1	5.56	0.51	0.72	7.63	0.72	0.63	6.75	0.63	5.30	0.49	0.3446	
Na-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
K	1.00	0.58	0.58	5.74	0.58	0.58	1.13	0.58	1.28	0.58	0.5306	
Ca	11.9	1.1	0.55	5.53	0.55	1.1	11.2	1.1	11.6	1.1	0.0109	
Mg	4.11	0.40	0.42	4.28	0.42	0.26	2.68	0.26	2.48	0.24	0.0165	
Fe	0.0361	0.0087	0.0087	0.0341	0.0087	0.029	0.277	0.029	0.244	0.025	0.0078	
Mn	0.239	0.026	0.014	0.120	0.014	0.015	0.127	0.015	0.024	0.010	0.0092	
Co	<0.0054	0.0054	0.0054	<0.0054	0.0054	0.0054	<0.0054	0.0054	<0.0054	0.0054	0.0049	
Mo	<0.0048	0.0048	0.0048	<0.0048	0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	0.0043	
Al	0.071	0.070	0.070	<0.070	0.070	0.070	0.199	0.070	0.118	0.070	0.0636	
As	<0.0052	0.0052	0.0052	0.0082	0.0052	0.052	0.086	0.052	<0.0052	0.0052	0.0047	
Se	<0.010	0.010	0.010	<0.010	0.010	0.010	<0.010	0.010	<0.010	0.010	0.0098	
Cd	<0.0034	0.0034	0.0034	<0.0034	0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	0.0031	
Be	<0.0005	0.0005	0.0005	<0.0005	0.0005	0.0005	<0.0005	0.0005	<0.0005	0.0005	0.0004	
Cu	<0.029	0.029	0.029	<0.029	0.029	0.029	<0.029	0.029	<0.029	0.029	0.0267	
Sb	<0.034	0.034	0.034	<0.034	0.034	0.034	<0.034	0.034	<0.034	0.034	0.0307	
Cr	<0.0004	0.0004	0.0004	0.0007	0.0004	0.0004	0.0004	0.0004	0.0014	0.0004	0.0004	
Ni	0.0065	0.0026	0.0026	<0.0026	0.0026	0.0026	0.0066	0.0026	0.0031	0.0026	0.0023	
Zn	<0.010	0.010	0.010	<0.010	0.010	0.010	0.016	0.010	<0.010	0.010	0.0098	
Ag	<0.015	0.015	0.015	<0.015	0.015	0.015	<0.015	0.015	<0.015	0.015	0.0137	
Tl	<0.0065	0.0065	0.0065	<0.0065	0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	0.0058	
Pb	<0.014	0.014	0.014	<0.014	0.014	0.014	<0.014	0.014	<0.014	0.014	0.0128	
Hg	<0.098	0.098	0.098	<0.098	0.098	0.098	<0.098	0.098	<0.098	0.098	0.0884	
Li	<0.040	0.040	0.040	<0.040	0.040	0.040	<0.040	0.040	<0.040	0.040	0.0368	
Te	<0.019	0.019	0.019	<0.019	0.019	0.019	<0.019	0.019	0.022	0.019	0.0172	
Sr	0.0763	0.0075	0.0025	0.0265	0.0025	0.0061	0.0617	0.0061	0.0565	0.0056	0.0007	
Ge	0.103	0.056	0.056	0.060	0.056	0.056	<0.056	0.056	<0.056	0.056	0.0512	
V	<0.018	0.018	0.018	<0.018	0.018	0.018	<0.018	0.018	0.023	0.018	0.0170	
Ba	0.0120	0.0026	0.0026	0.0082	0.0026	0.0026	0.0151	0.0026	0.0046	0.0026	0.0023	
B	0.065	0.022	0.022	<0.022	0.022	0.022	0.024	0.022	<0.022	0.022	0.0206	
Ti	<0.0065	0.0065	0.0065	<0.0065	0.0065	0.0065	0.0147	0.0065	0.0153	0.0065	0.0059	

< VALUE-LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
EPA/RSKRL/ADA, OK
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

TAG NO.	STATION	TIME	DATE	PR DIL	DIL	7201			7202			7203		
						VALUE	STDV +/-		VALUE	STDV +/-		VALUE	STDV +/-	LOD
Na-1	7200	KSMW-91	09:16	14-OCT-94	1.0000	4.81	0.44	5.45	6.83	0.64	8.43	0.80	0.3446	
Na-2	KSMW-91	09:17	14-OCT-94	1.0000	1.1100	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
K	7200	KSMW-91	09:16	14-OCT-94	1.0000	0.62	0.58	0.96	1.13	0.58	0.60	0.58	0.5306	
Ca	7200	KSMW-91	09:16	14-OCT-94	1.0000	7.73	0.77	7.55	14.8	1.4	19.0	1.9	0.0109	
Mg	7200	KSMW-91	09:16	14-OCT-94	1.0000	2.30	0.22	1.56	4.14	0.40	7.42	0.73	0.0165	
Fe	7200	KSMW-91	09:16	14-OCT-94	1.0000	0.0724	0.0088	0.476	0.0865	0.0099	0.0102	0.0087	0.0078	
Mn	7200	KSMW-91	09:16	14-OCT-94	1.0000	0.941	0.096	0.034	0.012	0.010	0.731	0.075	0.0092	
Co	7200	KSMW-91	09:16	14-OCT-94	1.0000	<0.0054	0.0054	<0.0054	<0.0054	0.0054	<0.0054	0.0054	0.0049	
Mo	7200	KSMW-91	09:16	14-OCT-94	1.0000	0.0102	0.0048	0.0081	<0.0048	0.0048	<0.0048	0.0048	0.0043	
Al	7200	KSMW-91	09:16	14-OCT-94	1.0000	<0.070	0.070	0.157	<0.070	0.070	0.123	0.070	0.0636	
As	7200	KSMW-91	09:16	14-OCT-94	1.0000	<0.0053	0.0053	0.0127	<0.0052	0.0052	<0.0053	0.0053	0.0047	
Se	7200	KSMW-91	09:16	14-OCT-94	1.0000	<0.010	0.010	<0.010	<0.010	0.010	<0.010	0.010	0.0098	
Cd	7200	KSMW-91	09:16	14-OCT-94	1.0000	<0.0034	0.0034	0.0042	<0.0034	0.0034	<0.0034	0.0034	0.0031	
Be	7200	KSMW-91	09:16	14-OCT-94	1.0000	<0.0005	0.0005	<0.0005	<0.0005	0.0005	<0.0005	0.0005	0.0004	
Cu	7200	KSMW-91	09:16	14-OCT-94	1.0000	0.051	0.029	0.034	<0.029	0.029	<0.029	0.029	0.0267	
Sb	7200	KSMW-91	09:16	14-OCT-94	1.0000	<0.034	0.034	0.034	<0.034	0.034	<0.034	0.034	0.0307	
Cr	7200	KSMW-91	09:16	14-OCT-94	1.0000	0.0009	0.0004	0.0007	<0.0004	0.0004	0.0005	0.0004	0.0004	
Ni	7200	KSMW-91	09:16	14-OCT-94	1.0000	<0.0026	0.0026	<0.0026	<0.0026	0.0026	0.0091	0.0026	0.0023	
Zn	7200	KSMW-91	09:16	14-OCT-94	1.0000	0.010	0.010	<0.010	<0.010	0.010	<0.010	0.010	0.0098	
Ag	7200	KSMW-91	09:16	14-OCT-94	1.0000	<0.015	0.015	<0.015	<0.015	0.015	<0.015	0.015	0.0137	
Tl	7200	KSMW-91	09:16	14-OCT-94	1.0000	<0.0065	0.0065	<0.0066	<0.0065	0.0065	<0.0065	0.0065	0.0058	
Pb	7200	KSMW-91	09:16	14-OCT-94	1.0000	<0.014	0.014	<0.014	<0.014	0.014	<0.014	0.014	0.0128	
Hg	7200	KSMW-91	09:16	14-OCT-94	1.0000	<0.098	0.098	<0.098	<0.098	0.098	<0.098	0.098	0.0884	
Li	7200	KSMW-91	09:16	14-OCT-94	1.0000	<0.040	0.040	<0.040	<0.040	0.040	<0.040	0.040	0.0368	
Te	7200	KSMW-91	09:16	14-OCT-94	1.0000	<0.019	0.019	0.042	<0.019	0.019	<0.019	0.019	0.0172	
Sr	7200	KSMW-91	09:16	14-OCT-94	1.0000	0.0266	0.0026	0.0347	0.0566	0.0056	0.109	0.010	0.0007	
Ge	7200	KSMW-91	09:16	14-OCT-94	1.0000	0.060	0.056	<0.056	<0.056	0.056	0.061	0.056	0.0512	
V	7200	KSMW-91	09:16	14-OCT-94	1.0000	<0.018	0.018	0.026	<0.018	0.018	<0.018	0.018	0.0170	
Ba	7200	KSMW-91	09:16	14-OCT-94	1.0000	<0.0026	0.0026	0.0081	0.0050	0.0026	0.0238	0.026	0.0023	
B	7200	KSMW-91	09:16	14-OCT-94	1.0000	<0.022	0.022	<0.022	<0.022	0.022	<0.022	0.022	0.0206	
Ti	7200	KSMW-91	09:16	14-OCT-94	1.0000	0.0258	0.0065	0.0418	<0.0065	0.0065	<0.0065	0.0065	0.0059	

< VALUE-LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
EPA/RSKRL/ADA, OK

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

TAG NO.	STATION	TIME	DATE	PR DIL	DIL	7205			7206			7207		
						VALUE	STDV +/-	LOD	VALUE	STDV +/-	LOD	VALUE	STDV +/-	LOD
7204	KSMW-508	09:24	14-OCT-94	1.0000	1.1100	3.33	0.38	0.0000	5.27	0.48	0.0000	7.77	0.73	0.3446
						0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
						<0.58	0.58	0.58	<0.58	0.58	0.58	1.57	0.58	0.5306
						3.05	0.30	0.30	8.00	0.80	0.41	19.4	1.9	0.0109
						0.893	0.083	0.083	2.05	0.19	0.12	6.30	0.63	0.0165
						0.0729	0.0087	0.0087	0.0248	0.0087	0.0087	6.59	0.66	0.0078
						0.034	0.010	0.010	<0.010	0.010	0.075	4.15	0.41	0.0092
						<0.0054	0.0054	0.0054	<0.0054	0.0054	0.0054	<0.0054	0.0054	0.0049
						<0.0048	0.0048	0.0048	<0.0048	0.0048	0.0048	<0.0048	0.0048	0.0043
						<0.070	0.070	0.070	0.109	0.070	0.070	0.073	0.070	0.0636
						0.0085	0.0052	0.0052	0.0083	0.0052	0.0053	0.0184	0.0064	0.0047
						<0.010	0.010	0.010	<0.010	0.010	0.010	<0.011	0.011	0.0098
						<0.0034	0.0034	0.0034	<0.0034	0.0034	0.0034	<0.0034	0.0034	0.0031
						<0.0005	0.0005	0.0005	<0.0005	0.0005	0.0005	<0.0005	0.0005	0.0004
						<0.029	0.029	0.029	<0.029	0.029	0.029	<0.029	0.029	0.0267
						<0.034	0.034	0.034	0.042	0.034	0.034	<0.034	0.034	0.0307
						0.0007	0.0004	0.0004	0.0013	0.0004	0.0004	0.0010	0.0004	0.0004
						<0.0026	0.0026	0.0026	0.0054	0.0026	0.0026	0.0062	0.0026	0.0023
						<0.010	0.010	0.010	<0.010	0.010	0.010	<0.010	0.010	0.0098
						0.015	0.015	0.015	<0.015	0.015	0.015	<0.015	0.015	0.0137
						<0.0065	0.0065	0.0065	<0.0065	0.0065	0.0065	<0.0065	0.0065	0.0058
						<0.014	0.014	0.014	0.016	0.014	0.014	0.015	0.014	0.0128
						<0.098	0.098	0.098	<0.098	0.098	0.098	<0.10	0.10	0.0884
						<0.040	0.040	0.040	<0.040	0.040	0.040	<0.040	0.040	0.0368
						<0.019	0.019	0.019	<0.019	0.019	0.019	<0.019	0.019	0.0172
						0.0024	0.0024	0.0024	0.0346	0.0034	0.0029	0.104	0.010	0.0007
						<0.056	0.056	0.056	<0.056	0.056	0.056	0.058	0.056	0.0512
						<0.018	0.018	0.018	0.028	0.018	0.018	0.021	0.018	0.0170
						0.0042	0.0026	0.0026	0.0054	0.0026	0.0026	0.0163	0.0026	0.0023
						<0.022	0.022	0.022	<0.022	0.022	0.022	<0.022	0.022	0.0206
						<0.0065	0.0065	0.0065	<0.0065	0.0065	0.0065	<0.0065	0.0065	0.0059

< VALUE-LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKRL/ADA, OK

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

7209				7210				7211			
KSMW-53				KSMW-50				KSMW-509			
09:35				09:37				09:39			
14-OCT-94				14-OCT-94				14-OCT-94			
1.0000				1.0000				1.0000			
1.1100				1.1100				1.1100			
ELEMENT	VALUE	STDV +/-	STDV +/-	VALUE	STDV +/-	STDV +/-	VALUE	VALUE	STDV +/-	STDV +/-	LOD
Na-1	7.29	0.68	0.56	6.10	0.56	0.38	3.27	3.27	0.38	0.3446	
Na-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
K	0.60	0.58	0.58	<0.58	0.58	0.58	<0.58	<0.58	0.58	0.5306	
Ca	18.8	1.8	1.1	11.3	1.1	0.42	2.83	2.83	0.28	0.0109	
Mg	10.5	1.0	0.23	2.41	0.23	0.087	0.863	0.863	0.080	0.0165	
Fe	46.9	4.6	0.0087	0.0405	0.0087	0.0095	0.0218	0.0218	0.0087	0.0078	
Mn	3.57	0.35	0.10	<0.10	0.10	0.10	0.289	0.289	0.031	0.0092	
Co	0.0060	0.0054	0.0054	<0.0054	0.0054	0.0054	<0.0054	<0.0054	0.0054	0.0049	
Mo	<0.0048	0.0048	0.0048	<0.0048	0.0048	0.0048	<0.0048	<0.0048	0.0048	0.0043	
Al	<0.070	0.070	0.070	<0.070	0.070	0.070	<0.070	<0.070	0.070	0.0636	
As	<0.0061	0.0061	0.0052	<0.0052	0.0052	0.0052	<0.0052	<0.0052	0.0052	0.0047	
Se	<0.021	0.021	0.010	<0.010	0.010	0.010	0.015	0.010	0.010	0.0098	
Cd	<0.0034	0.0034	0.0034	<0.0034	0.0034	0.0034	<0.0034	<0.0034	0.0034	0.0031	
Be	0.0010	0.0005	0.0005	<0.0005	0.0005	0.0005	<0.0005	<0.0005	0.0005	0.0004	
Cu	<0.029	0.029	0.029	<0.029	0.029	0.029	<0.029	<0.029	0.029	0.0267	
Sb	<0.037	0.037	0.034	<0.034	0.034	0.034	<0.034	<0.034	0.034	0.0307	
Cr	0.0015	0.0005	0.0004	<0.0004	0.0004	0.0004	<0.0004	<0.0004	0.0004	0.0004	
Ni	0.0028	0.0026	0.0026	<0.0026	0.0026	0.0026	<0.0026	<0.0026	0.0026	0.0023	
Zn	0.031	0.010	0.010	<0.010	0.010	0.010	<0.010	<0.010	0.010	0.0098	
Ag	<0.015	0.015	0.015	<0.015	0.015	0.015	<0.015	<0.015	0.015	0.0137	
Tl	<0.0065	0.0065	0.0065	<0.0065	0.0065	0.0065	<0.0065	<0.0065	0.0065	0.0058	
Pb	<0.014	0.014	0.014	<0.014	0.014	0.014	<0.014	<0.014	0.014	0.0128	
Hg	<0.29	0.29	0.098	<0.098	0.098	0.098	<0.098	<0.098	0.098	0.0884	
Li	<0.040	0.040	0.040	<0.040	0.040	0.040	<0.040	<0.040	0.040	0.0368	
Te	<0.019	0.019	0.019	<0.019	0.019	0.019	<0.019	<0.019	0.019	0.0172	
Sr	0.142	0.014	0.0062	0.0629	0.0062	0.0275	0.0233	0.0233	0.0222	0.0007	
Ge	<0.056	0.056	0.056	<0.056	0.056	0.056	<0.056	<0.056	0.056	0.0512	
V	<0.018	0.018	0.018	<0.018	0.018	0.018	<0.018	<0.018	0.018	0.0170	
Ba	0.0394	0.0038	0.0026	0.0039	0.0026	0.0026	0.0039	0.0039	0.0026	0.0023	
B	<0.023	0.023	0.022	<0.022	0.022	0.022	<0.022	<0.022	0.022	0.0206	
Ti	<0.0065	0.0065	0.0065	<0.0065	0.0065	0.0065	<0.0065	<0.0065	0.0065	0.0059	

< VALUE-LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
EPA/RSKRL/ADA, OK

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

TAG NO.	STATION	TIME	DATE	PR DIL	DIL	7213			7214			7215			
						VALUE	STDV +/-		VALUE	STDV +/-		VALUE	STDV +/-	LOD	
Na-1						0.40		10.8	1.0		4.61	0.42	4.56	0.41	0.3446
Na-2						0.0000		0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
K						0.58		0.89	0.58		<0.58	0.58	0.79	0.58	0.5306
Ca						21.6		31.4	3.1		4.20	0.42	7.81	0.78	0.0109
Mg						6.14		11.7	1.1		1.63	0.16	2.00	0.19	0.0165
Fe						9.74		2.45	0.24		54.5	5.4	0.0698	0.0087	0.0078
Mn						1.65		6.25	0.62		0.077	0.010	<0.010	0.010	0.0092
Co						<0.0054		0.0057	0.0054		0.0080	0.0054	<0.0054	0.0054	0.0049
Mo						0.0048		<0.0048	0.0048		<0.0048	0.0048	<0.0048	0.0048	0.0043
Al						0.070		<0.070	0.070		1.92	0.18	<0.070	0.070	0.0636
As						0.0054		<0.0075	0.0075		0.0065	0.0053	0.0231	0.0052	0.0047
Se						0.011		<0.010	0.010		<0.022	0.022	0.014	0.010	0.0098
Cd						0.0034		<0.0034	0.0034		<0.0034	0.0034	<0.0034	0.0034	0.0031
Be						0.0005		<0.0005	0.0005		0.0028	0.0005	<0.0005	0.0005	0.0004
Cu						0.029		<0.029	0.029		<0.029	0.029	<0.029	0.029	0.0267
Sb						0.034		<0.034	0.034		<0.038	0.038	0.042	0.034	0.0307
Cr						0.0004		0.0056	0.0005		0.0047	0.0005	<0.0004	0.0004	0.0004
Ni						0.0026		0.0040	0.0026		<0.0026	0.0026	0.0067	0.0026	0.0023
Zn						0.010		<0.010	0.010		0.027	0.010	<0.010	0.010	0.0098
Ag						0.015		<0.015	0.015		<0.015	0.015	<0.015	0.015	0.0137
Tl						0.0065		<0.0065	0.0065		<0.0066	0.0066	<0.0065	0.0065	0.0058
Pb						0.014		<0.014	0.014		<0.014	0.014	0.016	0.014	0.0128
Hg						0.10		<0.10	0.10		<0.35	0.35	<0.098	0.098	0.0884
Li						0.040		<0.040	0.040		<0.040	0.040	<0.040	0.040	0.0368
Te						0.019		<0.019	0.019		<0.019	0.019	0.046	0.019	0.0172
Sr						0.0761		0.195	0.019		0.0259	0.0025	0.0499	0.0049	0.0007
Ge						<0.056		<0.056	0.056		0.104	0.056	<0.056	0.056	0.0512
V						<0.018		<0.018	0.018		0.021	0.018	0.027	0.018	0.0170
Ba						0.0100		0.0513	0.0049		0.0155	0.0026	0.0037	0.0026	0.0023
B						<0.022		<0.022	0.022		<0.023	0.023	<0.022	0.022	0.0206
Ti						<0.0065		<0.0065	0.0065		0.0445	0.0065	<0.0065	0.0065	0.0059

< VALUE-LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
EPA/RSKRL/ADA, OK

RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

TAG NO.	STATION	TIME	DATE	PR DIL	DIL	7216				7217				7218				7219			
						VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-
Na-1						6.38	0.59	6.14	0.57	9.52	0.91	6.62	0.62	6.62	0.62	6.62	0.62	6.62	0.62	6.62	0.62
Na-2						0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
K						1.76	0.58	1.80	0.58	2.01	0.58	<0.58	<0.58	<0.58	<0.58	<0.58	<0.58	<0.58	<0.58	<0.58	<0.58
Ca						9.67	0.97	17.2	1.7	37.9	3.7	9.32	9.32	9.32	9.32	9.32	9.32	9.32	9.32	9.32	9.32
Mg						2.73	0.26	8.76	0.87	16.3	1.6	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53	4.53
Fe						0.126	0.013	3.39	0.34	17.0	1.7	0.0463	0.0463	0.0463	0.0463	0.0463	0.0463	0.0463	0.0463	0.0463	0.0463
Mn						0.172	0.019	3.90	0.39	8.04	0.80	0.276	0.276	0.276	0.276	0.276	0.276	0.276	0.276	0.276	0.276
Co						<0.0054	0.0054	<0.0054	0.0054	0.0074	0.0074	<0.0054	<0.0054	<0.0054	<0.0054	<0.0054	<0.0054	<0.0054	<0.0054	<0.0054	<0.0054
Mo						<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	<0.0048	<0.0048	<0.0048	<0.0048	<0.0048	<0.0048	<0.0048	<0.0048	<0.0048	<0.0048
Al						<0.070	0.070	<0.070	0.070	<0.070	0.070	<0.070	<0.070	<0.070	<0.070	<0.070	<0.070	<0.070	<0.070	<0.070	<0.070
As						0.0151	0.0052	0.0075	0.0062	0.0235	0.0095	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066	0.0066
Se						<0.010	0.010	<0.010	0.010	<0.011	0.011	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cd						<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	<0.0034	<0.0034	<0.0034	<0.0034	<0.0034	<0.0034	<0.0034	<0.0034	<0.0034	<0.0034
Be						<0.0005	0.0005	<0.0005	0.0005	<0.0006	0.0006	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cu						<0.029	0.029	<0.029	0.029	<0.029	0.029	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029
Sb						<0.034	0.034	<0.034	0.034	<0.034	0.034	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034
Cr						<0.0004	0.0004	<0.0004	0.0004	0.0008	0.0008	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
Ni						0.0055	0.0026	<0.0026	0.0026	0.0053	0.0053	<0.0026	<0.0026	<0.0026	<0.0026	<0.0026	<0.0026	<0.0026	<0.0026	<0.0026	<0.0026
Zn						<0.010	0.010	<0.010	0.010	0.015	0.015	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Ag						<0.015	0.015	<0.015	0.015	<0.015	0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Tl						<0.0065	0.0065	<0.0065	0.0065	<0.0066	0.0066	<0.0065	<0.0065	<0.0065	<0.0065	<0.0065	<0.0065	<0.0065	<0.0065	<0.0065	<0.0065
Pb						<0.014	0.014	<0.014	0.014	<0.014	0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014
Hg						<0.098	0.098	<0.098	0.098	<0.098	0.098	<0.098	<0.098	<0.098	<0.098	<0.098	<0.098	<0.098	<0.098	<0.098	<0.098
Li						<0.040	0.040	<0.040	0.040	<0.040	0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040
Te						<0.019	0.019	<0.019	0.019	0.026	0.026	<0.019	<0.019	<0.019	<0.019	<0.019	<0.019	<0.019	<0.019	<0.019	<0.019
Sr						0.0584	0.0057	0.102	0.010	0.182	0.182	0.0678	0.0678	0.0678	0.0678	0.0678	0.0678	0.0678	0.0678	0.0678	0.0678
Ge						<0.056	0.056	<0.056	0.056	<0.056	0.056	<0.056	<0.056	<0.056	<0.056	<0.056	<0.056	<0.056	<0.056	<0.056	<0.056
V						<0.018	0.018	<0.018	0.018	<0.018	0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018
Ba						0.0062	0.0026	0.0058	0.0026	0.0128	0.0128	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171	0.0171
B						<0.022	0.022	<0.022	0.022	<0.022	0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022
Ti						0.0172	0.0065	<0.0065	0.0065	<0.0065	0.0065	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081	0.0081

< VALUE-LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS
EPA/RSKRL/ADA, OK

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

TAG NO.	STATION	TIME	DATE	PR DIL	DIL	7220			7221			7222			7223		
						VALUE	STDV +/-		VALUE	STDV +/-		VALUE	STDV +/-		VALUE	STDV +/-	LOD
Na-1						7.34	0.69		7.34	0.69		11.4	1.1		10.9	1.0	0.3446
Na-2						0.0000	0.0000		0.0000	0.0000		0.0000	0.0000		0.0000	0.0000	0.0000
K						2.95	0.58		1.60	0.58		0.94	0.58		1.67	0.58	0.5306
Ca						23.5	2.3		14.5	1.4		17.4	1.7		22.0	2.2	0.0109
Mg						10.1	1.0		3.20	0.31		4.85	0.48		9.05	0.90	0.0165
Fe						0.0133	0.0087		0.0296	0.0087		0.264	0.028		0.078	0.010	0.0078
Mn						1.53	0.15		0.267	0.029		0.98	0.10		2.85	0.28	0.0092
Co						<0.0054	0.0054		<0.0054	0.0054		<0.0054	0.0054		<0.0054	0.0054	0.0049
Mo						<0.0048	0.0048		<0.0048	0.0048		<0.0048	0.0048		<0.0048	0.0048	0.0043
Al						0.110	0.070		<0.070	0.070		0.686	0.070		<0.070	0.070	0.0636
As						0.0250	0.0054		0.0110	0.0052		0.0083	0.0053		0.0229	0.0058	0.0047
Se						0.029	0.010		<0.010	0.010		<0.010	0.010		<0.010	0.010	0.0098
Cd						<0.0034	0.0034		0.0036	0.0034		<0.0034	0.0034		<0.0034	0.0034	0.0031
Be						<0.0005	0.0005		<0.0005	0.0005		<0.0005	0.0005		<0.0005	0.0005	0.0004
Cu						<0.029	0.029		<0.029	0.029		<0.029	0.029		<0.029	0.029	0.0267
Sb						0.050	0.034		<0.034	0.034		<0.034	0.034		<0.034	0.034	0.0307
Cr						0.0005	0.0004		<0.0004	0.0004		<0.0004	0.0004		<0.0004	0.0004	0.0004
Ni						0.0098	0.0026		0.0030	0.0026		0.0042	0.0026		0.0032	0.0026	0.0023
Zn						<0.010	0.010		<0.010	0.010		<0.010	0.010		<0.010	0.010	0.0098
Ag						0.018	0.015		<0.015	0.015		<0.015	0.015		<0.015	0.015	0.0137
Tl						<0.0065	0.0065		<0.0065	0.0065		<0.0065	0.0065		<0.0065	0.0065	0.0058
Pb						0.021	0.014		<0.014	0.014		<0.014	0.014		<0.014	0.014	0.0128
Hg						<0.098	0.098		<0.098	0.098		<0.098	0.098		<0.098	0.098	0.0884
Li						<0.040	0.040		<0.040	0.040		<0.040	0.040		<0.040	0.040	0.0368
Te						0.052	0.019		<0.019	0.019		<0.019	0.019		0.025	0.019	0.0172
Sr						0.121	0.012		0.0818	0.0081		0.117	0.011		0.113	0.011	0.0007
Ge						<0.056	0.056		<0.056	0.056		<0.056	0.056		<0.056	0.056	0.0512
V						0.039	0.018		<0.018	0.018		<0.018	0.018		<0.018	0.018	0.0170
Ba						0.0323	0.0030		0.0120	0.0026		0.0267	0.0026		0.0077	0.0026	0.0023
B						<0.022	0.022		<0.022	0.022		<0.022	0.022		0.023	0.022	0.0206
Ti						<0.0065	0.0065		0.0091	0.0065		0.0170	0.0065		<0.0065	0.0065	0.0059

< VALUE-LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
EPA/RSKRL/ADA, OK

RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

ELEMENT	7224			7225			7226			7227		
	VALUE	STDV +/-		VALUE	STDV +/-		VALUE	STDV +/-		VALUE	STDV +/-	LOD
Na-1	7.05	0.66		4.98	0.45		6.45	0.60		5.50	0.50	0.3446
Na-2	0.0000	0.0000		0.0000	0.0000		0.0000	0.0000		0.0000	0.0000	0.0000
K	2.00	0.58		<0.58	0.58		<0.58	0.58		<0.58	0.58	0.5306
Ca	12.5	1.2		31.9	3.1		13.1	1.3		13.4	1.3	0.0109
Mg	4.24	0.41		8.68	0.86		3.26	0.32		4.85	0.48	0.0165
Fe	0.0519	0.0087		16.2	1.6		<0.0087	0.0087		1.23	0.12	0.0078
Mn	0.217	0.024		2.55	0.25		0.016	0.010		2.02	0.20	0.0092
Co	<0.0054	0.0054		<0.0054	0.0054		<0.0054	0.0054		<0.0054	0.0054	0.0049
Mo	<0.0048	0.0048		<0.0048	0.0048		<0.0048	0.0048		<0.0048	0.0048	0.0043
Al	<0.070	0.070		<0.070	0.070		<0.070	0.070		<0.070	0.070	0.0636
As	0.0200	0.0052		<0.0057	0.0057		<0.0052	0.0052		<0.0182	0.0055	0.0047
Se	<0.010	0.010		<0.011	0.011		<0.010	0.010		<0.010	0.010	0.0098
Cd	<0.0034	0.0034		<0.0034	0.0034		<0.0034	0.0034		<0.0034	0.0034	0.0031
Be	<0.0005	0.0005		<0.0005	0.0005		<0.0005	0.0005		<0.0005	0.0005	0.0004
Cu	<0.029	0.029		<0.029	0.029		<0.029	0.029		<0.029	0.029	0.0267
Sb	<0.034	0.034		<0.034	0.034		<0.034	0.034		<0.034	0.034	0.0307
Cr	<0.0004	0.0004		<0.0004	0.0004		<0.0004	0.0004		<0.0004	0.0004	0.0004
Ni	0.0110	0.0026		0.0073	0.0026		<0.0026	0.0026		0.0045	0.0026	0.0023
Zn	0.017	0.010		0.056	0.010		<0.010	0.010		0.020	0.010	0.0098
Ag	<0.015	0.015		<0.015	0.015		<0.015	0.015		<0.015	0.015	0.0137
Tl	<0.0065	0.0065		<0.0065	0.0065		<0.0065	0.0065		<0.0065	0.0065	0.0058
Pb	0.014	0.014		<0.014	0.014		<0.014	0.014		<0.014	0.014	0.0128
Hg	<0.098	0.098		<0.12	0.12		<0.098	0.098		<0.098	0.098	0.0884
Li	<0.040	0.040		<0.040	0.040		<0.040	0.040		<0.040	0.040	0.0368
Te	0.025	0.019		<0.019	0.019		<0.019	0.019		0.027	0.019	0.0172
Sr	0.0630	0.0062		0.105	0.010		0.0772	0.0076		0.0797	0.0079	0.0007
Ge	<0.056	0.056		0.073	0.056		<0.056	0.056		<0.056	0.056	0.0512
V	0.019	0.018		<0.018	0.018		<0.018	0.018		<0.018	0.018	0.0170
Ba	0.0281	0.0026		0.0145	0.0026		<0.0026	0.0026		0.0043	0.0026	0.0023
B	<0.022	0.022		<0.022	0.022		<0.022	0.022		<0.022	0.022	0.0206
Ti	0.0233	0.0065		<0.0065	0.0065		<0.0065	0.0065		<0.0065	0.0065	0.0059

< VALUE-LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS
EPA/RSKRL/ADA, OK

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

TAG NO.	STATION	TIME	DATE	PR DIL	DIL	7229				7230				7231			
						KSMW-89	10:15	14-OCT-94	1.0000	1.1100	KSMW-3A	10:17	14-OCT-94	1.0000	1.1100	KSMW-462C	10:18
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	3.46	0.38	5.09	0.46	4.43	0.40	5.45	0.50	0.3446								
Na-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000								0.0000
K	<0.58	0.58	0.75	0.58	<0.58	0.58	<0.58	0.58	<0.58								0.5306
Ca	9.62	0.96	8.92	0.89	8.93	0.89	10.2	1.0	0.0109								0.0109
Mg	2.61	0.25	4.48	0.44	3.16	0.31	2.92	0.28	0.0165								0.0165
Fe	0.0366	0.0087	0.0792	0.0097	0.0121	0.0087	0.0193	0.0087	0.0078								0.0078
Mn	<0.010	0.010	1.36	0.13	1.36	0.13	<0.010	0.010	0.0092								0.0092
Co	<0.0054	0.0054	<0.0054	0.0054	<0.0054	0.0054	<0.0054	0.0054	0.0049								0.0049
Mo	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	0.0043								0.0043
Al	<0.070	0.070	<0.070	0.070	<0.070	0.070	<0.070	0.070	0.0636								0.0636
As	<0.0052	0.0052	<0.0054	0.0054	<0.0054	0.0054	<0.0052	0.0052	0.0047								0.0047
Se	<0.010	0.010	<0.010	0.010	<0.010	0.010	<0.010	0.010	0.0098								0.0098
Cd	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	0.0031								0.0031
Be	<0.0005	0.0005	<0.0005	0.0005	<0.0005	0.0005	<0.0005	0.0005	0.0004								0.0004
Cu	<0.029	0.029	<0.029	0.029	<0.029	0.029	<0.029	0.029	0.0267								0.0267
Sb	<0.034	0.034	<0.034	0.034	<0.034	0.034	<0.034	0.034	0.0307								0.0307
Cr	<0.0004	0.0004	<0.0004	0.0004	<0.0004	0.0004	<0.0004	0.0004	0.0004								0.0004
Ni	<0.0026	0.0026	0.0036	0.0026	<0.0026	0.0026	<0.0026	0.0026	0.0023								0.0023
Zn	<0.010	0.010	0.024	0.010	<0.010	0.010	<0.010	0.010	0.0098								0.0098
Ag	<0.015	0.015	<0.015	0.015	<0.015	0.015	<0.015	0.015	0.0137								0.0137
Tl	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	0.0058								0.0058
Pb	<0.014	0.014	<0.014	0.014	<0.014	0.014	<0.014	0.014	0.0128								0.0128
Hg	<0.098	0.098	<0.098	0.098	<0.098	0.098	<0.098	0.098	0.0884								0.0884
Li	<0.040	0.040	<0.040	0.040	<0.040	0.040	<0.040	0.040	0.0368								0.0368
Te	<0.019	0.019	<0.019	0.019	<0.019	0.019	<0.019	0.019	0.0172								0.0172
Sr	0.0497	0.0049	0.0492	0.0048	0.0510	0.0050	0.0572	0.0056	0.0007								0.0007
Ge	<0.056	0.056	0.070	0.056	0.058	0.056	<0.056	0.056	0.0512								0.0512
V	<0.018	0.018	<0.018	0.018	<0.018	0.018	<0.018	0.018	0.0170								0.0170
Ba	<0.0026	0.0026	0.0045	0.0026	0.0082	0.0026	0.0036	0.0026	0.0023								0.0023
B	<0.022	0.022	0.022	0.022	<0.022	0.022	<0.022	0.022	0.0206								0.0206
Ti	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	<0.0065	0.0065	0.0055								0.0055

< VALUE-LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS
EPA/RSKRL/ADA, OK

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

CONCENTRATION IN: MG/L

TAG NO. 7232
STATION KSMW-435
TIME 10:20
DATE 14-OCT-94
PR DIL 1.0000
DIL 1.1100

7233
KSMW-10A
10:22
14-OCT-94
1.0000
1.1100

7234
KSMW-8A
10:23
14-OCT-94
1.0000
1.1100

7235
ESMW-88
10:25
14-OCT-94
1.0000
1.1100

ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	11.7	1.1	11.5	1.1	17.5	1.7	13.3	1.2	0.3446
Na-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
K	0.92	0.58	2.64	0.58	2.71	0.58	2.54	0.58	0.5306
Ca	27.0	2.7	20.6	2.0	42.7	4.2	17.3	1.7	0.0109
Mg	10.6	1.0	6.53	0.65	16.8	1.7	4.39	0.43	0.0165
Fe	0.251	0.028	1.57	0.15	32.1	3.2	0.359	0.038	0.0078
Mn	5.27	0.53	1.29	0.13	14.9	1.4	2.21	0.22	0.0092
Co	<0.0054	0.0054	0.0058	0.0054	0.0169	0.0054	<0.0054	0.0054	0.0049
Mo	<0.0048	0.0048	<0.0048	0.0048	<0.0048	0.0048	0.0132	0.0048	0.0043
Al	<0.070	0.070	0.352	0.070	0.099	0.070	0.133	0.070	0.0636
As	<0.0070	0.0070	0.0108	0.0054	0.024	0.017	<0.0056	0.0056	0.0047
Se	<0.010	0.010	<0.010	0.010	<0.014	0.014	<0.010	0.010	0.0098
Cd	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	<0.0034	0.0034	0.0031
Be	<0.0005	0.0005	<0.0005	0.0005	<0.0006	0.0006	<0.0005	0.0005	0.0004
Cu	<0.029	0.029	<0.029	0.029	<0.029	0.029	<0.029	0.029	0.0267
Sb	<0.034	0.034	<0.034	0.034	<0.035	0.035	<0.034	0.034	0.0307
Cr	<0.0004	0.0004	0.0007	0.0004	0.0014	0.0004	<0.0004	0.0004	0.0004
Ni	<0.0026	0.0026	0.0053	0.0026	0.0090	0.0026	0.0043	0.0026	0.0023
Zn	<0.010	0.010	<0.010	0.010	0.012	0.010	0.014	0.010	0.0098
Ag	<0.015	0.015	<0.015	0.015	<0.015	0.015	<0.015	0.015	0.0137
Tl	<0.0065	0.0065	<0.0065	0.0065	<0.0068	0.0068	<0.0088	0.0088	0.0058
Pb	<0.014	0.014	<0.014	0.014	0.094	0.014	<0.014	0.014	0.0128
Hg	<0.099	0.099	<0.098	0.098	<0.18	0.18	<0.098	0.098	0.0884
Li	<0.040	0.040	<0.040	0.040	<0.040	0.040	<0.040	0.040	0.0368
Te	<0.019	0.019	<0.019	0.019	0.046	0.019	0.028	0.019	0.0172
Sr	0.131	0.013	0.111	0.011	0.355	0.035	0.0574	0.0057	0.0007
Ge	<0.056	0.056	<0.056	0.056	<0.056	0.056	<0.056	0.056	0.0512
V	<0.018	0.018	<0.018	0.018	0.023	0.018	<0.018	0.018	0.0170
Ba	0.0064	0.0026	0.0212	0.0026	0.109	0.010	0.0143	0.0026	0.0023
B	<0.022	0.022	<0.022	0.022	<0.022	0.022	<0.022	0.022	0.0206
Ti	<0.0065	0.0065	0.0279	0.0065	<0.0065	0.0065	0.129	0.012	0.0059

< VALUE-LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
EPA/RSKRL/ADA, OK



Ref: 94-JH15/vg

September 29, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift *SAV*

Dear Don:

Attached are TOC results for a set of 38 groundwater samples submitted to ManTech September 13, 1994 under Service Request #SF-0-76. TOC determinations were begun and completed September 28, 1994 using RSKSOP-102.

A known AQC sample was analyzed with your samples for quality control. Sample numbers KSMW 3 Rep. 2 and ESMW 12A Rep 2, were filtered through a 0.45 μ m Millipore filter and analyzed in duplicate due to high readouts.

If you have any questions concerning this data, please feel free to contact me.

Sincerely,

A handwritten signature in cursive script that reads "Jeff Hickerson".

Jeff Hickerson

xc: R.L. Cosby
J.L. Seeley *jls*

UNDWATERS FROM KING SALMON FOR TOC (SR# SF-0-76)

SAMPLE	MG/L OC	SAMPLE	MG/L OC
ESMW 1A REP 2	27.3	KSMW 460 REP 2dup	5.8.
ESMW 1A REP 2dup	27.2	KSMW 462C REP 2	4.8
ESMW 1B REP 2	1.6	KSMW 501 REP 2	7.6
KSMW 50 REP 2	21.3	KSMW 508 REP 2	1.4
KSMW 52 REP 2	16.4		
KSMW 53 REP 2	1.1	WPO32-I	43.6
KSMW 53 REP 2dup	1.1		44.1
KSMW 60 REP 2	12.1		44.3
KSMW 88 REP 2	3.9		43.4
KSMW 89 REP 2	2.3		43.3
KSMW 90 REP 2	4.0		43.5
KSMW 500 REP 2	17.7		43.4
KSMW 500 REP 2dup	0.7		43.7
KSMW 506 REP 2	1.5		
KSMW 509 REP 2			
KSWP 1 REP 2	7.9		
KSWP 2 REP 2	12.7		
ESMW 2A REP 2	6.5		
ESMW 2A REP 2dup	6.5		
ESMW 2B REP 2	2.6		
KSMW 3 REP 2	65.6		
KSMW 3 REP 2dup	65.9		
ESMW 3A REP 2	6.9		
ESMW 3B REP 2	1.3		
ESMW 4A REP 2	8.2		
ESMW 4A REP 2dup	8.2		
ESMW 4B REP 1	2.1		
ESMW 4B REP 2	2.2		
ESMW 6B REP 2	3.4		
ESMW ES 7A REP 2	2.7		
ESMW ES 7B REP 2	1.9		
ESMW ES 7B REP 2dup	2.0		
ESMW 12A REP 2	35.5		
ESMW 12A REP 2dup	35.5		
KSMW 51 REP 2	12.6		
KSMW 91 REP 2	0.7		
KSMW 92 REP 2	6.5		
KSMW 93 REP 2	4.3		
KSMW 93 REP 2dup	4.3		
KSMW 94 REP 2	1.4		
KSMW 95 REP 2	4.5		
KSMW 435 REP 1	5.5		
KSMW 435 REP 2	5.0		
KSMW 460 REP 2	5.8		

TRUE VALUE: WPO32-I = 44.0 MG/L OC

MANTECH TECHNOLOGY

Ref: 94-BN52/vg

September 29, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

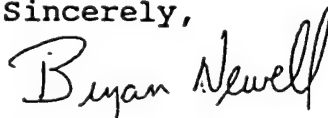
THRU: S.A. Vandegrift *SAV*

Dear Don:

Please find attached results for methane and ethylene on King Salmon, AK samples as per Service Request #SF-0-76. Samples were received on 9/23/94 and analyzed on 9/26-27/94. Samples were prepared as described in the paper "Dissolved Oxygen and Methane in Water by a GC Headspace Equilibration Technique", by Kampbell et al., in International Journal of Environmental Analytical Chemistry, Volume 36, pp. 249-257. Analysis and calculations were performed as per RSKSOP-147.

If you have any questions, please feel free to see me.

Sincerely,



Bryan Newell

xc: R.L. Cosby
J.L. Seeley *jls*
J.T. Wilson

ANALYZED 9/26/94

SAMPLE	METHANE	ETHYLENE
LAB BLANK	BLQ	ND
KSWP1	0.768	ND
KSWP2	1.351	ND
KSWP3	5.612	ND
ESMW2A	0.002	ND
ESMW2A LAB DUP	0.002	ND
ESMW2B	0.063	ND
ESMW3A	0.041	ND
ESMW3B	BLQ	ND
ESMW4A	0.002	ND
ESMW4B	BLQ	ND
ESMW4B FIELD DUP	BLQ	ND
ESMW6B	BLQ	ND
KSMW ES7A	BLQ	ND
KSMW ES7B	0.186	ND
ESMW12A	3.004	ND
KSMW51	0.162	ND
KSMW91	BLQ	ND
KSMW91 LAB DUP	BLQ	ND

ANALYZED 9/27/94

SAMPLE	METHANE	ETHYLENE
LAB BLANK	BLQ	ND
KSMW92	0.001	ND
KSMW93	0.004	ND
KSMW94	0.087	ND
KSMW95	0.060	ND
KSMW435	0.135	ND
KSMW435 FIELD DUP	0.137	ND
KSMW460B	BLQ	ND
KSMW462C	0.072	ND
KSMW501	0.004	ND
KSMW508	0.011	ND
KSMW508 LAB DUP	0.010	ND

SAMPLE	METHANE	ETHYLENE
10 PPM CH4	9.87	ND
100 PPM CH4	98.73	ND
990 PPM CH4	1011.95	ND
1 % CH4	1.01	ND
4 % CH4	4.08	ND
10 % CH4	9.97	ND
10 PPM C2H4	ND	10.01
100 PPM C2H4	ND	100.00

MANTECH

Ref: 94-MW99/vg
94-TH92/vg
94-LP101/vg

September 30, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don:

Attached are inorganic results for a set of 14 samples from King Salmon, Alaska submitted to MERSC September 29 as a part of Service Request #SF-0-76. The analyses were done September 30 using EPA Methods 353.1 and 120.1 and Water's capillary electrophoresis method N-601.

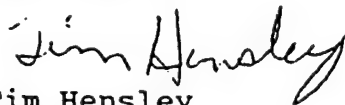
Blanks, spikes, duplicates and known AQC samples were analyzed along with your samples for quality control.

If you have any questions concerning this data, please feel free to contact any one of us.

Sincerely,



Mark White



Tim Hensley



Lynda Pennington

xc: R.L. Cosby
J.L. Seeley *js*

Sample	mg/L <u>Cl⁻</u>	mg/L <u>SO₄⁼</u>	mg/L <u>NO₂⁻ + NO₃⁻ (N)</u>	<u>μS/cm</u> <u>Conductivity</u>
ESMW-5A	2.96	3.21	0.37	239
ESMW-5A Dup	----	----	----	240
ESMW-5B	3.51	2.79	0.11	134
ESMW-8A	4.33	<.5	0.06	432
ESMW-8B	2.57	1.36	0.06	182
ESMW-10A	4.57	8.54	0.30	204
ESMW-10B	3.53	2.40	0.10	110
ESMW-10B Dup	3.61	2.45	0.10	----
ESMW-12A	3.66	<.5	*	63.1
ESMW-12A Dup	----	----	----	63.1
ESMW-13A	4.16	.66	0.09	155
ESMW-14A	3.67	3.81	0.11	79.7
ESMW-15A	5.21	5.38	0.14	251
ESMW-15B	2.20	1.55	0.11	212
ESMW-15B Dup	2.15	1.56	----	----
KSMW-507	4.37	3.56	0.09	64.0
KSMW-50	*	*	0.26	*
KS-DK1A	3.12	3.04	*	334
Blank	<.5	<.5	<.05	.66
WP032	107	74.5	2.60	1413
WP032 T.V.	106	75.0	2.81	1413
Spike Rec.	98%	98%	101%	----

* No sample received for this parameter.

MANTECH

Ref: 94-LB39
October 5, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
919 Kerr Research Drive
Ada, OK 74820

THRU: Steve Vandegrift *SV*

Dear Don:

Please find attached the analytical results for Service Request SF-0-76 for the analysis of aqueous samples from King Salmon, AK, for the determination of BTEXXX & TMBs and Total Fuel Carbon. A total of 49 samples were received in capped, 40 mL VOA vials on September 23 & 29, 1994. Samples were analyzed between September 27 & October 5, 1994. Some of the samples arrived in duplicate. All samples were stored at 4°C until analyzed and were acquired and processed using the MAXIMA data system. A 5 point (1-1000 ppb) external calibration curve was used to determine the concentration for all compounds.

The QC True Value for all the compounds is 50 ppb.

RSKSOP-133 "Simultaneous Analysis of Aromatics and Total Fuel Carbon by Dual Column-Dual Detector for Ground Water Samples" was used for these analyses.

Sincerely,

Lisa R. Black
Lisa R. Black

xc: R.L. Cosby
J.L. Seeley *jls*

*Reference to
new 503.1*

*purge: prep
2 claims: 10000
FID - not working -
FID -*

*total FID run and
divided sum of just BTEX
TMB.
then lab results from FID
then 0.35*

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

SAMPLE NAME	BENZENE	TOLUENE	ETHYLBENZENE	p-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB	Fuel Carbon
100 PPB	9.70E+01	9.68E+01	9.70E+01	9.74E+01	9.73E+01	9.72E+01	9.75E+01	9.82E+01	9.85E+01	N/A
QC, OBSERVED, PPB	5.01E+01	5.02E+01	5.07E+01	5.04E+01	4.97E+01	5.10E+01	5.00E+01	5.05E+01	4.98E+01	N/A
GC LAB BLANK, PPB	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A
ES MW-2A	ND	8.95E+00	BLQ	BLQ	2.49E+00	1.40E+00	ND	BLQ	BLQ	1.21E+01
ES MW-3A	9.13E+01	1.30E+01	BLQ	9.82E+01	2.72E+00	1.54E+00	ND	BLQ	ND	1.75E+01
ES MW-3B	ND	BLQ	ND	BLQ	BLQ	ND	ND	BLQ	ND	BLQ
ES MW-ES7A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-ES7B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-51	3.43E+00	2.05E+02	1.08E+02	1.31E+02	2.74E+02	1.47E+02	7.38E+01	1.01E+02	6.24E+01	1.56E+03
KS MW-88	ND	ND	BLQ	2.62E+00	BLQ	ND	6.17E+00	3.62E+00	1.45E+01	2.43E+02
KS MW-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-93	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
10 PPB	9.21E+00	9.45E+00	9.62E+00	9.55E+00	9.54E+00	9.61E+00	9.65E+00	9.57E+00	9.73E+00	N/A
KS MW-94	ND	ND	ND	BLQ	ND	ND	ND	ND	ND	BLQ
KS MW-95	1.80E+02	4.70E+02	3.27E+01	3.88E+01	1.08E+02	6.60E+01	9.38E+00	2.50E+01	1.46E+01	8.76E+02
KS MW-435	5.86E+01	7.05E+00	6.78E+01	9.33E+01	1.38E+02	1.25E+02	2.79E+01	7.25E+01	4.18E+01	7.95E+02
KS MW-460B	ND	BLQ	ND	ND	ND	ND	ND	ND	ND	BLQ
KS MW-462C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-501	ND	ND	ND	ND	BLQ	ND	ND	ND	ND	BLQ
KS MW-501 Duplicate	ND	ND	ND	BLQ	BLQ	ND	ND	ND	ND	BLQ
ES MW-1A	1.05E+03	6.47E+03	3.58E+02	3.98E+02	1.17E+03	6.90E+02	9.09E+01	2.84E+02	1.80E+02	1.01E+04
ES MW-1B	5.59E+00	5.91E+01	2.09E+01	2.89E+01	8.72E+01	3.66E+01	6.57E+01	1.44E+02	8.14E+01	1.85E+03
KS MW-500	4.36E+00	8.07E+00	6.46E+01	1.05E+02	1.27E+02	1.07E+02	1.09E+02	2.18E+02	1.60E+02	2.18E+03
GC LAB BLANK, PPB	ND	BLQ	ND	ND	ND	ND	ND	ND	ND	N/A
1000 PPB	9.77E+02	9.38E+02	9.28E+02	9.29E+02	9.29E+02	9.39E+02	9.59E+02	9.65E+02	9.79E+02	N/A
KS MW-50	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-52	2.31E+01	9.43E+00	2.83E+01	2.00E+01	3.74E+00	1.70E+00	3.41E+00	ND	3.62E+00	2.50E+02
KS MW-52 Duplicate	2.46E+01	1.02E+01	3.08E+01	2.20E+01	3.72E+00	1.85E+00	3.26E+00	ND	4.63E+00	3.34E+02
KS MW-53	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-53 Duplicate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-60	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-89	ND	ND	BLQ	ND	ND	ND	ND	ND	ND	BLQ
KS MW-90	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-506	ND	6.60E+00	ND	ND	ND	ND	ND	ND	ND	7.77E+01
KS MW-509	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS IN-RIVER	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS IN-RIVER Duplicate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QC, OBSERVED, PPB	4.81E+01	4.81E+01	4.52E+01	4.82E+01	4.77E+01	4.92E+01	4.91E+01	4.98E+01	4.92E+01	N/A
ES MW-5A	4.55E+01	8.14E+00	3.85E+01	1.65E+02	1.39E+02	3.18E+02	5.65E+01	1.15E+02	9.19E+01	1.27E+03
ES MW-5B	ND	ND	9.22E+01	ND	BLQ	ND	ND	ND	ND	2.74E+01
ES MW-8A	2.74E+02	2.97E+03	3.75E+02	2.91E+02	6.90E+02	6.61E+02	1.24E+02	3.52E+02	3.34E+02	7.71E+03
ES MW-8B	ND	1.41E+00	BLQ	ND	BLQ	1.27E+00	BLQ	ND	3.05E+00	3.61E+01
KS WP-1	BLQ	BLQ	ND	BLQ	BLQ	BLQ	1.18E+00	1.20E+00	1.32E+00	6.66E+00
KS WP-2	1.04E+00	1.82E+00	ND	9.62E+01	ND	ND	ND	ND	ND	5.87E+00
KS WP-2 Duplicate	BLQ	1.56E+00	ND	BLQ	ND	ND	ND	ND	ND	3.14E+00
KS WP-3	1.69E+00	2.59E+01	ND	ND	ND	ND	ND	ND	ND	2.47E+01

ND = None Detected; BLQ = Below Limit of Quantitation, 1 ppb; N/A = Not Analyzed

10 PPB	9.53E+00	9.82E+00	1.01E+01	9.96E+00	9.97E+00	9.96E+00	9.91E+00	1.01E+01	N/A
ES MW-2B	ND	ND	ND	ND	ND	ND	ND	ND	ND
ES MW-4A	ND	3.04E+00	ND	ND	1.28E+00	BLQ	ND	ND	4.57E+00
ES MW-4B	ND	ND	ND	ND	ND	ND	ND	ND	ND
ES MW-6B	ND	1.72E+00	ND	ND	BLQ	ND	ND	ND	2.18E+00
✓ ES MW-9A	5.90E+00	ND	1.07E+01	7.80E+00	7.57E+00	5.08E+00	1.03E+00	ND	4.92E+00
KS MW-91	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-507	ND	ND	ND	ND	ND	ND	ND	ND	ND
KS MW-508	ND	ND	ND	ND	ND	ND	ND	ND	ND
✓ ES MW-10A	1.40E+01	9.65E-01	2.07E+01	3.26E+01	3.47E+01	3.33E+01	1.61E+01	3.65E+01	4.96E+02
✓ ES MW-10B	9.92E+01	9.90E+01	ND	BLQ	BLQ	BLQ	1.53E+00	1.83E+00	1.52E+01
100 PPB	4.96E+00	BLQ	9.91E+01	9.85E+01	9.97E+01	9.89E+01	9.83E+01	1.01E+02	N/A
ES MW-12A	3.12E+00	ND	ND	BLQ	ND	ND	ND	ND	7.70E+00
ES MW-13A	ND	ND	1.34E+00	1.59E+00	BLQ	ND	ND	ND	1.22E+01
ES MW-14A	ND	ND	ND	ND	ND	ND	ND	ND	ND
ES MW-15A	ND	ND	2.50E+00	2.96E+00	ND	ND	ND	1.18E+00	9.27E+01
ES MW-15B	BLQ	5.57E+00	1.72E+01	3.29E+01	6.50E+00	2.13E+00	1.25E+00	1.57E+01	4.99E+02
OC, OBSERVED, PPB	4.85E+01	4.88E+01	4.95E+01	4.90E+01	4.85E+01	4.98E+01	5.22E+01	4.95E+01	N/A

ND = None Detected; BLQ = Below Limit of Quantitation, 1 ppb; N/A = Not Analyzed

MANTECH

Ref: 94-BN53/vg

October 11, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift *SAV*

Dear Don:

Please find attached results for methane and ethylene on King Salmon, AK samples as per Service Request #SF-0-76. Samples were received on 9/30/94 and analyzed on 10/3/94. Samples were prepared and calculations were done as per RSKSOP-175 (draft). Analysis was performed as per RSKSOP-147.

If you have any questions, please feel free to see me.

Sincerely,

Bryan Newell

Bryan Newell

xc: R.L. Cosby
J.L. Seeley *if*
J.T. Wilson

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

SF-0-76 DATA

ANALYZED 10/3/94

SAMPLE	METHANE	ETHYLENE
LAB BLANK	BLQ	ND
ESMW5A	BLQ	ND
ESMW5B	0.002	ND
ESMW8A	3.582	0.005
ESMW8B	0.133	ND
ESMW10A	1.501	ND
ESMW10B	0.010	ND
ESMW10B LAB DUP	0.010	ND
ESMW13A	4.234	ND
ESMW14A	0.033	ND
ESMW15A	7.636	ND
ESMW15B	0.005	ND
KSMW507	0.011	ND
" FIELD DUP	0.013	ND

SAMPLE	METHANE	ETHYLENE
10 PPM CH4	10.00	ND
100 PPM CH4	103.12	ND
990 PPM CH4	1002.43	ND
1 % CH4	1.01	ND
4 % CH4	4.01	ND
10 % CH4	9.99	ND
10 PPM C2H4	ND	10.21
100 PPM C2H4	ND	99.98

LOWER LIMITS OF QUANTITATION

METHANE	ETHYLENE
0.001	0.003

UNITS FOR THE SAMPLES ARE mg/L.

UNITS FOR THE STANDARDS CORRESPOND TO
THE UNITS IN THE SAMPLE COLUMN.

ND DENOTES NONE DETECTED.

BLQ DENOTES BELOW LIMIT OF QUANTITATION.

LOWER LIMITS OF QUANTITATION

METHANE ETHYLENE

0.001

0.003

UNITS FOR THE SAMPLES ARE mg/L.

UNITS FOR THE STANDARDS CORRESPOND TO
THE UNITS IN THE SAMPLE COLUMN.

ND DENOTES NONE DETECTED.

BLQ DENOTES BELOW LIMIT OF QUANTITATION.



Ref: 94-JH16/vg

October 12, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift *SAV*

Dear Don:

Attached are TOC results for 12 additional groundwater samples submitted to ManTech Environmental September 13, 1994 under Service Request #SF-0-76. TOC determinations were begun September 30, 1994 and completed October 11, 1994 using RSKSOP-102.

A known AQC sample was analyzed with your samples for quality control and samples ESMW 8A REP 2 and ESMW 15A REP 2 were analyzed in duplicate due to high readouts.

If you have any questions concerning this data, please feel free to contact me.

Sincerely,

Jeff Hickerson

xc: R.L. Cosby
J.L. Seeley

MORE G. WATERS FROM KING SALMON FOR TOC (SR# SF-0-76)

SAMPLE	MG/L OC
ESMW 5A	5.7
ESMW 5B REP 2	1.4
ESMW 8A REP 2	70.0
ESMW 8A REP 2dup	69.8
ESMW 8B REP 2	4.0
ESMW 10A REP 2	9.9
ESMW 10A REP 2dup	10.4
ESMW 10B REP 2	2.6
ESMW 13A REP 2	12.4
ESMW 14A REP 2	2.2
ESMW 15A REP 2	24.9
ESMW 15A REP 2dup	24.6
ESMW 15B REP 2	5.6
ESMW 15B REP 2dup	5.5
KSMW 507 REP 1	1.6
KSMW 507 REP 2	1.6
KSMW 507 REP 2dup	1.6
WPO32-I	43.1
	45.0
	45.2
WPO32-II	8.5

TRUE VALUES: WPO32-I = 44.0 MG/L OC
WPO32-II = 9.60 MG/L OC



Ref: 94-JH17/vg

October 12, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift *SAV*

Dear Don:

Attached are TOC results for a set of 17 soil samples submitted to ManTech Environmental September 13, 1994 under Service Request #SF-0-76. TOC determinations were begun October 3, 1994 and completed October 12, 1994 using RSKSOP-102 and RSKSOP-120.

A Leco standard soil and a known AQC sample were both analyzed with your samples for quality control.

If you have any questions concerning this data, please feel free to contact me.

Sincerely,

Jeff Hickerson
Jeff Hickerson

xc: R.L. Cosby
J.L. Seeley

SOIL SAMPLES FROM KING SALMON FORD (SR# SF-0-76)

SAMPLES	SOIL FILT %TOC	SOLIDS %TOC	TOTAL %TOC	MEAN %TOC	SAMPLES	SOIL FILT %TOC	SOLIDS %TOC	TOTAL %TOC	MEAN %TOC
KCECSB 1 14.5-16' #1	0.002	0.016	0.018	0.020	ESMW 10 13-15' #1	0.147	0.923	1.070	1.053
KCECSB 1 14.5-16' #2	0.002	0.020	0.022		ESMW 10 13-15' #2	0.147	0.889	1.036	
ESMW 1B 10-12' #1	0.009	0.028	0.037	0.036	ESMW 13B 4-5' #1	0.349	1.502	1.851	1.878
ESMW 1B 10-12' #2	0.004	0.031	0.035		ESMW 13B 4-5' #2	0.356	1.548	1.904	
ESMW 1B 12-14' #1	0.002	0.016	0.018	0.016	LECO		0.982		
ESMW 1B 12-14' #2	0.002	0.012	0.014				0.975		
ESMW 2B 13-15' #1	0.002	0.015	0.017	0.018			0.996		
ESMW 2B 13-15' #2	0.002	0.016	0.018		WFO32-II				
ESMW 2B 13-15' #1A	0.002	0.021	0.023	0.022		8.5 MG/L			
ESMW 2B 13-15' #2A	<0.001	0.021	0.021			8.7 MG/L			
ESMW 2B 17-19' #1	<0.001	0.012	0.012	0.015		8.5 MG/L			
ESMW 2B 17-19' #2	0.002	0.016	0.018			8.4 MG/L			
ESMW 2B 40-42' #1	<0.001	0.018	0.018	0.017		8.5 MG/L			
ESMW 2B 40-42' #2	<0.001	0.016	0.016						
ESMW 3B 13-15' #1	0.002	0.015	0.017	0.018					
ESMW 3B 13-15' #2	0.002	0.016	0.018						
ESMW 5B 13-15' #1	<0.001	0.015	0.015	0.016					
ESMW 5B 13-15' #2	0.002	0.015	0.017						
ESMW 5B 16-18' #1	<0.001	0.017	0.017	0.017					
ESMW 5B 16-18' #2	<0.001	0.016	0.016						
ESMW 7B 11-13' #1	0.002	0.014	0.016	0.016					
ESMW 7B 11-13' #2	0.002	0.014	0.016						
ESMW 8B 12-14' #1	0.033	0.102	0.132	0.132					
ESMW 8B 12-14' #2	0.030	0.102	0.132						
ESMW 8B 16-18' #1	<0.001	0.026	0.026	0.024					
ESMW 8B 16-18' #2	0.002	0.019	0.021						
ESMW 10 0-2' #1	0.102	1.217	1.319	1.310					
ESMW 10 0-2' #2	0.102	1.199	1.301						
ESMW 10 3-5' #1	0.066	0.720	0.786	0.759					
ESMW 10 3-5' #2	0.067	0.664	0.731						

TRUE VALUES: LECO = 1.00 +/- 0.04%
WFO32-II = 9.60 MG/L OC

MANTECH TECHNOLOGY

Ref: 94-RC39/vg

November 1, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift *SAV*

Dear Don:

Attached is a report of the data generated from the analyses of 22 sample core extracts from King Salmon AFB, AK. The extracts, which were submitted under Service Request #SF-0-76, were analyzed for total fuel content as JP-4 jet fuel only. The reported values for fuel carbon were computed from the JP-4 determinations. I have also attached a report of the quality control analyses that were performed concurrently with the sample analyses.

Data quantification, peak identification, component concentration calculations, and dilution factor corrections were performed with MAXIMA chromatography software. JP-4 data was quantified with a 7-point external standard calibration curve ranging from 50-50,000 ng/ μ l.

The Minimum Quantifiable Limit of JP-4 in these samples is 15.03 μ g/g. Please refer to ManTech report letter 93-RC19/vg, dated October 29, 1993, for a detailed explanation of the calculations used to arrive at this value.

Sample extracts were received October 3, 1994. Analyses were started October 12, 1994 and completed October 14, 1994. Sample extracts and quality control samples were analyzed according to RKSOP-72, Rev. #1, excepting the modifications listed in the attached outline.

Sincerely,

Randy Callaway
Randy Callaway

xc: R.L. Cosby
J.L. Seeley *jls*

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

SR#SF- / Kampbell / King Salmon AFB all conc. are g

Sample ID. Dilution Factor JP-4 Fuel Carbon (JP-4 x 0.85)

ES1B 10-12'	1	2130.00	1810.00
ES1B 10-12' TCE	1	1670.00	1420.00
ES1B 12-14'	1	8.03	6.83
ES1B 12-14' TCE	1	7.26	6.17
ES2B 13-15'	1	0.09	0.08
ES2B 17-19'	1	0.07	0.06
ES2B 40-42'	1	0.38	0.33
ES3B 13-15'	1	0.27	0.23
ES5B 13-15'	1	0.03	0.02
ES5B 16-18'	1	0.32	0.27
ES7B 11-13'	1	0.13	0.11
ES7B ?	1	0.83	0.71
ESM8 16-18'	1	11.00	9.35
ESM8B 12-14'	1	36.00	30.60
ESM10 0-2'	1	36.60	31.10
ESM10 3-5'	1	7.85	6.67
ESM10 13-15'	1	3.12	2.65
ES10 0-2'	1	31.00	26.40
ES10 3-5'	1	28.60	24.30
ES10 13-15'	1	-0.77	0.66
ES13B 4-5'	1	0.67	0.57
ECSB1 14.5-16'	1	0.18	0.15

NOTE: all reported values are corrected for dilution factors where applicable

THIS REPORT (([CLARK.ICAP]LIST.LST;3376) WAS GENERATED FROM [CLARK.ICAP]OUTPUT.DAT;1941

PROJECT: ALASKA WATER SAMPLES
WILSON/COOK
TA5

THIS REPORT WAS GENERATED WITH THE FOLLOWING INFORMATION:

ERROR LEVEL PERCENTAGE : 10%

STATISTICAL SENSITIVITIES WITH A 2.0 SIGMA INTERVAL WERE USED

CONCENTRATION IN: MG/L

THE CONSTANT FILES USED:

[CLARK.ICAP]TYPE1.AMAX;1
[CLARK.ICAP]TYPE1.XOCA;1
[CLARK.ICAP]TYPE1.XOCB;1
[CLARK.ICAP]TYPE1.XOCC;1
[CLARK.ICAP]TYPE1.STD1;1
[CLARK.ICAP]TYPE1.STD2;1
[CLARK.ICAP]TYPE1.STD3;1
[CLARK.ICAP]TYPE1.STD4;1
[CLARK.ICAP]TYPE1.STD5;1
[CLARK.ICAP]TYPE1.XSS1;1
[CLARK.ICAP]TYPE1.XSS2;1
[CLARK.ICAP]TYPE1.FIXX;1
[CLARK.ICAP]TYPE1.LCN;54

LCN TIME: 11:10:15 LCN DATE: 14-OCT-94 FILTER FACTOR: 0.000002

THE DATA FILES USED:

[CLARK.ICAP]IC0001.DAT;2854
[CLARK.ICAP]TAG.DAT;2898
[CLARK.ICAP]OUTPUT.DAT;1941
[CLARK.ICAP]OUTPUT.LST;1858
[CLARK.ICAP]ARCH.DAT;15

SR#SF- / Kampbell / QC Table all pic. are ng/ul

Samp. D. Date Analyzed JP-4

blank MeCl2	12OCT94	1.44
Method blank		2.82
100 ng/ul jp4		72.00
1000 ng/ul jp4		980.00
10000 ng/ul jp4		9470.00

MeCl2 = methylene chloride solvent blank
jp4 = JP-4 jet fuel standard

I. HP5890 GC - OPERATING CONDITIONS

- A. Instrument Control
 - 1. Analyses: "EGLIN AFB"
 - 2. Program: "RWC-AS10"
 - 3. Calibration: "BTEX-13JUN94"
- B. Temperature Program
 - 1. Initial Temp & Time: 10°C for 3.00 min
 - 2. Level 1: Rate = 4°C/min to 70°C, Final Time = 0.00
 - 3. Level 2: Rate = 1.0°C/min to 75°C, Final Time = 0.00
 - 4. Level 3: Rate = 10°C/min to 290°C, Final Time = 15.50
 - 5. Run Time: 60.00 min
 - 6. Oven Equilibration Time: 1.00 min
- C. Miscellaneous
 - 1. Peak Width: 0.02
 - 2. Attenuation: 2⁵
 - 3. Chart Speed: 0.50
 - 4. Threshold = 0
 - 5. Offset = 10%

II. MAXIMA PEAK INTEGRATION

- A. Peak Detection Parameters
 - 1. Baseline Points: 18
 - 2. Filter Window (in points): 9
 - 3. Intg. Sensitivity (coarse): 10.50 $\mu\text{V/sec}$
 - 4. Intg. Sensitivity (fine): 5.00 $\mu\text{V/sec}$
 - 5. Skim Ratio: 100.00
- B. Peak Rejection Criteria
 - 1. Minimum Area: 2000 $\mu\text{V-sec}$
 - 2. Minimum Height: 300.0 μV
 - 3. Minimum Width: 3.00 sec
- C. Integration Events
 - 1. 0.00: Disable Peak Skimming
 - 2. 0.00: Disable Peak Detection
 - 3. 7.00: Enable Peak Detection
 - 4. 21.97: Set Baseline
 - 5. 27.13: Set Baseline
 - 6. 32.30: Set Baseline
 - 7. 36.80: Set Baseline
 - 8. 39.59: Set Baseline
 - 9. 41.52: Set Baseline

III. MAXIMA DATA ACQUISITION

- A. Preacquisition Delay: 7.00 min
- B. Duration: 43.00 min
- C. Rate: 3.00 points/sec
- D. Run Time: 50.00 min

IV. MAXIMA CALIBRATION CURVES

- A. JP-4
 - 1. Calibration Range = 50 - 50,000 ng/ μl
 - 2. Summation of all peaks detected from 7.00 - 50.00 minutes

MANTECH TECH

Ref: 94-JAD43

November 1, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SAV

Dear Don:

As requested in Service Request # SF-0-76, headspace GC/MS analysis of 25 King Salmon water samples for volatile organic compounds was completed. The samples were received on September 23, 29, 1994 and analyzed on October 17-19, 1994. RSKSOP-148 (Determination of Volatile Organic Compounds in Water by Automated Headspace Gas Chromatography/Mass Spectrometry (Saturn II Ion Trap Detector) was used for this analysis.

An internal standard calibration method was established for 10 chlorinated and 6 aromatic compounds. The standard curves were prepared from 1.0 to 4000 ppb. The lower calibration limits were 1.0 ppb.

The samples not requiring dilution were prepared by adding 10 ml of sample to a headspace vial containing 2 g of sodium chloride (NaCl). 8 μ l of 125 μ g/ml fluorobenzene was added to this 10 ml liquid volume before the vial was capped. The diluted samples were prepared by adding an appropriate volume of sample (X) to a headspace vial containing 2 g of NaCl and 10 - X ml of water. The internal standard was then added and the vial was capped.

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

A dilution corrected quantitation report for the samples, lab duplicates, field duplicates, QC standards, and lab blanks is presented in Tables 1 & 2.

If you should have any questions, please feel free to contact me.

Sincerely,

John Allen Daniel
John Allen Daniel

xc: R.L. Cosby

G.B. Smith

D.D. Fine

J.L. Seeley *jls*

Table 1. Quantitation Report for S.R. # SF-0-76 from King Salmon.

Concentration = ppb

Compound	ESMW 1A	ESMW 1A Field Dup 1/2 DIL	ESMW 1B	ESMW 2A	ESMW 2B	ESMW 3A	ESMW 3B	ESMW 4A	ESMW 4A Field Dup	ESMW 4B
VINYL CHLORIDE	---	---	---	---	---	---	---	---	---	---
1,1-DICHLOROETHENE	---	---	---	---	---	---	---	---	---	---
T-1,2-DICHLOROETHENE	---	---	---	---	---	---	---	---	---	---
C-1,2-DICHLOROETHENE	---	---	---	---	---	---	---	---	---	---
1,1,1-TRICHLOROETHANE	7.5	7.0	---	1.3	---	---	---	---	---	---
CARBON TETRACHLORIDE	---	---	---	---	---	---	---	---	---	---
BENZENE	1160	1032	5.4	---	---	1.0	---	---	---	---
1,2-DICHLOROETHANE	---	---	---	---	---	---	---	---	---	---
TRICHLOROETHENE	---	---	---	---	---	---	---	---	---	---
TOLUENE	*****	6770	52.7	8.9	---	12.8	---	3.0	3.1	---
TETRACHLOROETHENE	---	---	---	---	---	---	---	---	---	---
CHLOROBENZENE	---	---	---	---	---	---	---	---	---	---
ETHYLBENZENE	346	340	18.1	1.0	---	1.0	---	1.0	1.0	---
m+p-Xylene	1680	1570	102	3.5	---	3.8	---	2.0	1.8	---
o-Xylene	692	662	34.2	1.5	---	1.7	---	1.0	1.0	---
Compound	ESMW 5A	ESMW 5A Lab Dup	ESMW 5B	ESMW 6B	KSMW- ES 7A	KSMW- ES 7B	ESMW 13A	ESMW 13A Lab Dup	KSMW 51	KSMW 88
VINYL CHLORIDE	---	---	---	---	---	---	---	---	---	---
1,1-DICHLOROETHENE	---	---	---	---	---	---	---	---	---	---
T-1,2-DICHLOROETHENE	---	---	---	---	---	---	---	---	---	---
C-1,2-DICHLOROETHENE	---	---	---	---	---	---	---	---	---	---
1,1,1-TRICHLOROETHANE	8.3	8.6	---	---	---	---	---	---	---	13.7
CARBON TETRACHLORIDE	---	---	---	---	---	---	---	---	---	---
BENZENE	46.8	47.8	---	---	---	---	2.6	2.6	3.1	---
1,2-DICHLOROETHANE	---	---	---	---	---	---	---	---	---	---
TRICHLOROETHENE	---	---	---	---	---	---	---	---	---	---
TOLUENE	8.4	8.8	1.0	1.6	---	---	---	---	214	---
TETRACHLOROETHENE	---	---	---	---	---	---	---	---	---	---
CHLOROBENZENE	---	---	---	---	---	---	---	---	---	---
ETHYLBENZENE	36.8	36.0	1.1	---	---	---	1.4	1.4	109	1.0
m+p-Xylene	287	291	1.0	1.2	---	---	2.3	2.2	427	3.3
o-Xylene	302	318	---	1.0	---	---	1.0	1.0	156	---

DIL = Dilution Dup = Duplicate --- = Below Calibration Limit(1.0 ppb) ***** = Above Calibration Limit(4000 ppb)

Table 2. Quantitation Report for S.R. # SF-0-76 from King Salmon.

Concentration = ppb

Compound	KSMW 92	KSMW 93	KSMW 93 Field Dup	KSMW 94	KSMW 95	KSMW 95 Lab Dup	KSMW 95 Field Dup	KSMW 435	KSMW 460B	KSMW 462C	KSMW 500
VINYL CHLORIDE	---	---	---	---	---	---	---	---	---	---	---
1,1-DICHLOROETHENE	---	---	---	---	---	---	---	---	---	---	---
T-1,2-DICHLOROETHENE	---	---	---	---	---	---	---	---	---	---	---
C-1,2-DICHLOROETHENE	---	---	---	---	---	---	---	---	---	---	---
1,1,1-TRICHLOROETHANE	---	---	---	---	1.3	1.3	1.5	1.9	2.1	---	---
CARBON TETRACHLORIDE	---	---	---	---	---	---	---	---	---	---	---
BENZENE	---	---	---	---	199	197	198	35.6	---	---	2.9
1,2-DICHLOROETHANE	---	---	---	---	---	---	---	---	---	---	---
TRICHLOROETHENE	---	---	---	---	---	---	---	---	---	---	---
TOLUENE	---	---	---	---	494	473	506	3.2	1.0	---	3.2
TETRACHLOROETHENE	---	---	---	---	---	---	---	---	---	---	---
CHLOROBENZENE	---	---	---	---	---	---	---	---	---	---	---
ETHYLBENZENE	---	---	---	---	34.2	32.5	35.2	28.8	---	---	60.8
m+p-XYLENE	---	---	---	---	149	148	153	95.3	---	---	204
o-XYLENE	---	---	---	---	70.6	67.9	70.7	53.4	---	---	99.2

Compound	KSMW 501	QC1017D	QC1017E	QC1017F	QC1017G	QC1017H	QC1017I	QC1019A	QC1019B	BL1017A	BL1017B
VINYL CHLORIDE	---	50 ppb	200 ppb	20 ppb	200 ppb	20 ppb	200 ppb	20 ppb	200 ppb	BLANK	BLANK
1,1-DICHLOROETHENE	---	47.7	174	19.0	180	19.6	181	18.1	---	---	---
T-1,2-DICHLOROETHENE	---	50.9	197	20.2	210	20.1	199	19.6	201	---	---
C-1,2-DICHLOROETHENE	---	48.7	206	20.8	209	20.8	205	21.0	207	---	---
1,1,1-TRICHLOROETHANE	---	49.4	212	20.1	208	20.1	208	19.7	202	---	---
CARBON TETRACHLORIDE	---	---	201	20.6	203	20.7	206	20.0	203	---	---
BENZENE	---	50.3	190	20.0	200	20.9	199	20.0	201	---	---
1,2-DICHLOROETHANE	---	49.8	208	21.2	205	20.7	208	20.6	207	---	---
TRICHLOROETHENE	---	52.4	214	22.2	203	20.4	217	21.9	209	---	---
TOLUENE	---	50.6	217	22.9	215	22.6	221	25.8	228	---	---
TETRACHLOROETHENE	---	45.2	196	19.9	191	19.9	194	19.6	191	---	---
CHLOROBENZENE	---	49.0	195	19.1	202	20.3	196	19.4	204	---	---
ETHYLBENZENE	---	48.8	209	21.6	205	20.3	204	20.5	197	---	---
m+p-XYLENE	---	46.7	190	18.1	189	19.8	188	19.0	190	---	---
o-XYLENE	---	46.8	389 **	37.2 *	380 **	36.6 *	374 **	37.1 *	377 **	---	---
	---	45.2	203	20.3	201	19.8	193	19.8	202	---	---

Dup = Duplicate --- = Below Calibration Limit(1.0 ppb) * = 40 ppb ** = 400 ppb *** = Not Included In QC QC = Quality Control Std. BL = Blank

SAMPLE	BENZENE	TOLUENE	EB	P-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB
ECSB114.5-16'	BLQ	7.17E-03	BLQ	BLQ	7.94E-03	6.15E-03	BLQ	6.53E-03	BLQ
ES-100-2'	2.10E-02	8.54E-03	1.53E-01	2.68E-01	3.64E-01	4.26E-01	5.06E-01	8.26E-01	5.69E-01
ES-103-5'	2.99E-02	1.22E-02	2.40E-01	3.71E-01	5.18E-01	4.51E-01	5.56E-01	9.63E-01	5.48E-01
ES-1013-15'	BLQ	BLQ	BLQ	6.80E-03	BLQ	BLQ	ND	BLQ	ND
ES13B4-5'	BLQ	BLQ	6.73E-03	8.08E-03	BLQ	5.89E-03	ND	BLQ	ND
ES1B10-12'	1.61E+00	5.13E+01	1.31E+01	1.40E+01	4.03E+01	1.76E+01	1.09E+01	2.31E+01	8.91E+00
ES1B12-14'	8.62E-01	2.76E+00	2.26E-01	2.54E-01	6.81E-01	3.85E-01	8.09E-02	2.40E-01	1.20E-01
ES2B13-15'	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	ND	BLQ	BLQ
ES2B17-19'	ND	BLQ	BLQ	BLQ	BLQ	BLQ	ND	ND	ND
ES2B40-42'	BLQ	BLQ	ND	ND	ND	ND	ND	ND	ND
ES3B13-15'	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	ND	ND	ND
ES5B13-15'	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	ND	BLQ	BLQ
ES5B16-18'	ND	BLQ	ND	ND	ND	ND	ND	ND	ND
ES7B(?) 11'	1.48E-02	1.06E-01	1.76E-02	2.03E-02	5.54E-02	2.94E-02	1.15E-02	2.88E-02	1.24E-02
ES7B11-13'	ND	BLQ	ND	ND	ND	ND	ND	ND	ND
ESMW100-2'	4.45E-02	1.38E-02	2.01E-01	3.45E-01	4.66E-01	5.26E-01	5.26E-01	9.29E-01	5.88E-01
ESMW103-5'	2.46E-02	1.53E-02	6.19E-02	9.82E-02	1.17E-01	1.15E-01	1.09E-01	2.01E-01	1.19E-01
ESMW1013-15'	BLQ	BLQ	6.51E-03	1.06E-02	BLQ	BLQ	BLQ	6.40E-03	ND
ESMW816-18'	6.73E-03	5.73E-02	1.13E-02	1.26E-02	1.82E-02	2.03E-02	2.45E-02	4.51E-02	1.89E-02
ESMW8B12-14'	7.36E-02	6.75E-01	1.05E-01	9.29E-02	1.71E-01	1.84E-01	9.49E-02	2.04E-01	1.36E-01
ES1B10-12'	1.36E+00	3.97E+01	9.83E+00	1.04E+01	3.06E+01	1.34E+01	8.43E+00	1.83E+01	7.03E+00
ES1B12-14'	5.17E-01	1.88E+00	1.72E-01	1.96E-01	5.24E-01	3.01E-01	7.22E-02	2.13E-01	1.08E-01
100	1.00E+02	1.00E+02	1.00E+02	9.98E+01	1.01E+02	1.00E+02	1.01E+02	1.01E+02	9.99E+01
10	1.07E+01	1.03E+01	1.04E+01	1.06E+01	9.98E+00	1.05E+01	1.08E+01	1.06E+01	1.03E+01
1QC	9.77E-01	9.62E-01	9.79E-01	9.74E-01	9.46E-01	9.66E-01	9.69E-01	9.51E-01	9.49E-01
1	9.56E-01	9.63E-01	9.45E-01	9.47E-01	9.91E-01	9.62E-01	9.51E-01	9.73E-01	9.67E-01
1	9.25E-01	9.34E-01	9.06E-01	9.16E-01	9.65E-01	9.37E-01	9.34E-01	9.30E-01	9.49E-01
0.1	1.04E-01	1.04E-01	1.03E-01	1.01E-01	9.72E-02	1.01E-01	9.63E-02	1.06E-01	1.01E-01
0.1	9.31E-02	9.43E-02	9.42E-02	9.29E-02	9.44E-02	9.27E-02	8.80E-02	8.55E-02	9.43E-02
METHODBLANK	BLQ	ND	ND	ND	ND	ND	ND	ND	ND

QC SUMMARY (ug/ml)

Analyst: David A. Kovacs

BLQ<0.02 ug/ml

Printed: 10/21/94 1 of 1

MANTECH

Ref: 94-DK28/vg

October 28, 1994

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift *SAV*

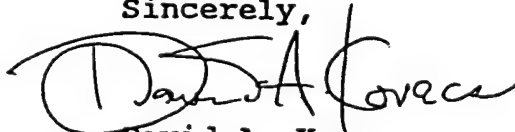
Dear Steve:

This report contains GC/MSD data for methylene chloride core extracts from King Salmon, AK, quantitated for trichloroethene (TCE) and tetrachloroethene (PCE) performed under Service Request SF-0-76. In a previous report (Ref: 94-DK25/vg, dated October 24, 1994) I presented data for aromatic compounds (BTEXXTMB) quantitated from these same extracts.

The analytical method was a modification of RSKSOP-124. Cool (38°C) on-column injection (0.5 µl) was used with electronic pressure control (EPC) set for a constant flow of 0.9 ml/min. A 30M X 0.25 mm Restek Stabilwax (Crossbonded Carbowax-PEG, 0.5 µm film) capillary GC column with 9 inch long X 0.53 mm ID uncoated capillary precolumn was used. Quantitation was based on calibration curves of a single target ion for each compound with the addition of up to two qualifier ions recorded to verify chromatographic separation or purity. The ions chosen were those listed in EPA method 524.2 Revision 3.0. A high level (0.05-50 µg/ml) and low level (0.05-5 µg/ml) calibration curve was applied to each sample for quantitation. Complete reports detailing the acquisition method and calibration curves have been recorded. The samples were extracted October 3, 1994 by Mark Blankenship and analyzed for TCE and PCE by GC/MSD on October 26, 1994.

If I can be of further assistance, please feel free to contact me.

Sincerely,


David A. Kovacs

xc: R.L. Cosby
J.L. Seeley *js*
G. Smith

<u>SAMPLE</u>	TCE	PCE
ECSB114.5-16'	1.87E-02	BLQ
ES-100-2'	ND	BLQ
ES-103-5'	BLQ	3.49E-01
ES-1013-15'	2.12E-02	9.11E-02
ES1B10-12'	ND	BLQ
ES1B12-14'	ND	BLQ
ES13B4-5'	BLQ	BLQ
ES2B13-15'	ND	BLQ
ES2B17-19'	ND	BLQ
ES2B40-42'	ND	BLQ
ES3B13-15'	ND	BLQ
ES5B13-15'	ND	BLQ
ES5B16-18'	ND	BLQ
ES7B?	ND	BLQ
ES7B11-13'	ND	BLQ
ESMW816-18'	ND	BLQ
ESMW8B12-14'	ND	BLQ
ESMW100-2'	BLQ	BLQ
ESMW103-5'	BLQ	BLQ
ESMW1013-15'	BLQ	BLQ
TCEES1B10-12'	ND	1.29E-01
TCEES1B12-14'	ND	BLQ

QC Summary
(ug/ml)

Method Blank	ND	BLQ
0.05	4.82E-02	4.91E-02
0.05	5.09E-02	5.04E-02
0.50	4.52E-01	4.72E-01
0.50	5.48E-01	5.28E-01
5.00	5.00E+00	5.00E+00
50.00	5.22E+01	5.24E+01
8.0 qc	8.19E+00	8.22E+00
40 QC	4.13E+01	4.10E+01

SAMPLING LOCATION Upper Naknek
SAMPLING DATE(S) 8/15 - 8/25/94

GROUND WATER SAMPLING RECORD - MONITORING WELL 507
(number)

REASON FOR SAMPLING: ☒ Regular Sampling; ☐ Special Sampling;
DATE AND TIME OF SAMPLING: 9-22-94, 1994 17:15 a.m./p.m.

SAMPLE COLLECTED BY: KJTH of ES

WEATHER: 21°

DATUM FOR WATER DEPTH MEASUREMENT (Describe):

MONITORING WELL CONDITION:

☒ LOCKED:

☒ UNLOCKED

WELL NUMBER (IS - IS NOT) APPARENT

STEEL CASING CONDITION IS: Oh

INNER PVC CASING CONDITION IS: Oh

WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT

☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR

☐ MONITORING WELL REQUIRED REPAIR (describe):

Check-off

1 ☒ EQUIPMENT CLEANED BEFORE USE WITH Alconox, Acetone, and Distilled H₂O 5 min
Items Cleaned (List): All equipment used in sampling

2 ☒ PRODUCT DEPTH _____ FT. BELOW DATUM
Measured with: Oil/ Water Interface Probe

WATER DEPTH 41.26 FT. BELOW DATUM
Measured with: Water Level Probe

3 ☐ WATER-CONDITION BEFORE WELL EVACUATION (Describe):
Appearance: Clear
Odor: _____
Other Comments: _____

4 ☐ WELL EVACUATION:
Method: Pump / In
Volume Removed: 0 gallons
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors: _____
Other comments: _____

5 [] SAMPLE EXTRACTION METHOD:

[] Bailer made of: _____
 [] Pump, type: _____
 [] Other, describe: _____

Sample obtained is [] GRAB; [] COMPOSITE SAMPLE

6 [] ON-SITE MEASUREMENTS:

Temp: <u>7.8° C</u>	Measured with: <u>Omm</u>
pH: <u>6.4</u>	Measured with: _____
Conductivity: _____	Measured with: _____
Dissolved Oxygen: <u>1.6 mg/L</u>	Measured with: <u>Omm</u>
Redox Potential: <u>1950</u>	Measured with: _____
Salinity: _____	Measured with: _____
Nitrate: _____	Measured with: _____
Sulfate: _____	Measured with: _____
Ferrous Iron: <u>0.2 mg/L</u>	Measured with: _____
Other: <u>Al = 680</u>	<u>Mn = 2.1 mg/L</u>

7 [] SAMPLE CONTAINERS (material, number, size): _____

8 [] ON-SITE SAMPLE TREATMENT:

[] Filtration: Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____

[] Preservatives added:
 Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____

9 [] CONTAINER HANDLING:

[] Container Sides Labeled
 [] Container Lids Taped
 [] Containers Placed in Ice Chest

10 [] OTHER COMMENTS: _____

SAMPLING LOCATION Fire Training Area FT-01_
SAMPLING DATE(S) 8/15 - 8/25/94_____

GROUND WATER SAMPLING RECORD - MONITORING WELL 501
(number)

REASON FOR SAMPLING: [x] Regular Sampling; [] Special Sampling;

DATE AND TIME OF SAMPLING: 9-16, 1994 9:15 a.m./p.m.

SAMPLE COLLECTED BY: KC TH EHA of ES

WEATHER: cal & clear

DATUM FOR WATER DEPTH MEASUREMENT (Describe): _____

MONITORING WELL CONDITION:

☒ LOCKED:

[] UNLOCKED

WELL NUMBER (IS IS NOT) APPARENT

STEEL CASING CONDITION IS: Good

INNER PVC CASING CONDITION IS: Good

WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT

[] DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR

[] MONITORING WELL REQUIRED REPAIR (describe): - New lock

Check-off

1 [x]

EQUIPMENT CLEANED BEFORE USE WITH Alconox, Acetone, and Distilled H₂O

Items Cleaned (List): All equipment used in sampling H₂O - neutral

2 [x]

PRODUCT DEPTH _____ FT. BELOW DATUM

Measured with: Oil/ Water Interface Probe _____

WATER DEPTH 12.5' bloc FT. BELOW DATUM

Measured with: Water Level Probe _____

3 []

WATER-CONDITION BEFORE WELL EVACUATION (Describe):

Appearance: Slightly cloudy just

Odor: _____

Other Comments: _____

4 []

WELL EVACUATION:

Method: Peristaltic pump

Volume Removed: 1.5 - well purged and had to be

Observations: Water (slightly - very) cloudy revised exp. occasionally

Water level (rose - fell - no change) fell

Water odors: _____

Other comments: _____

5 [] SAMPLE EXTRACTION METHOD:

[] Bailer made of: _____
 [] Pump, type: _____
 [] Other, describe: _____

Sample obtained is [] GRAB; [] COMPOSITE SAMPLE

6 [] ON-SITE MEASUREMENTS:

Temp: 52 C Measured with: _____
 pH: 6.0 Measured with: _____
 Conductivity: _____ Measured with: _____
 Dissolved Oxygen: 3.6 Measured with: Drawn
 Redox Potential: 186 Measured with: _____
 Salinity: _____ Measured with: _____
 Nitrate: _____ Measured with: _____
 Sulfate: _____ Measured with: _____
 Ferrous Iron: _____ Measured with: _____
 Other: CO₂ = 40 mg/L, Mn = < .1 mg/L

7 [] SAMPLE CONTAINERS (material, number, size): _____

8 [] ON-SITE SAMPLE TREATMENT:

[] Filtration: Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____

[] Preservatives added: _____
 Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____

9 [] CONTAINER HANDLING:

[] Container Sides Labeled
 [] Container Lids Taped
 [] Containers Placed in Ice Chest

10 [] OTHER COMMENTS: _____

SAMPLING LOCATION Upper Naknek _____

SAMPLING DATE(S) 8/15 - 8/25/94 _____

GROUND WATER SAMPLING RECORD - MONITORING WELL ESM4 - 15B
(number)

REASON FOR SAMPLING: ☒ Regular Sampling; ☐ Special Sampling;

DATE AND TIME OF SAMPLING: 9-22-94, 1994 14:00 a.m./p.m. (p.m.)

SAMPLE COLLECTED BY: KATH - EPA of ES

WEATHER: _____

DATUM FOR WATER DEPTH MEASUREMENT (Describe): _____

MONITORING WELL CONDITION:

☐ LOCKED:

☒ UNLOCKED

WELL NUMBER (IS - IS NOT) APPARENT

STEEL CASING CONDITION IS: OK

INNER PVC CASING CONDITION IS: OK

WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT

☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR

☐ MONITORING WELL REQUIRED REPAIR (describe): _____

Check-off

1 ☒

EQUIPMENT CLEANED BEFORE USE WITH Alconox, Acetone, and Distilled H2O 5- material

Items Cleaned (List): All equipment used in sampling _____

2 ☒

PRODUCT DEPTH _____ FT. BELOW DATUM

Measured with: Oil/ Water Interface Probe _____

WATER DEPTH 14.40' bhc FT. BELOW DATUM

Measured with: Water Level Probe _____

3 ☐

WATER-CONDITION BEFORE WELL EVACUATION (Describe):

Appearance: OK - clear

Odor: _____

Other Comments: _____

4 ☐

WELL EVACUATION:

Method: Parallel

Volume Removed: 6 gallons

Observations: Water (slightly - very) cloudy

Water level (rose - fell - no change)

Water odors: _____

Other comments: _____

5 [] SAMPLE EXTRACTION METHOD:

[] Bailer made of: _____
 [] Pump, type: _____
 [] Other, describe: _____

Sample obtained is [] GRAB; [] COMPOSITE SAMPLE

6 [] ON-SITE MEASUREMENTS:

Temp: <u>7.5 °C</u>	Measured with: <u>Omn</u>
pH: <u>7.0</u>	Measured with: _____
Conductivity: _____	Measured with: _____
Dissolved Oxygen: <u>0.2 mg/L</u>	Measured with: <u>Omn</u>
Redox Potential: <u>30</u>	Measured with: _____
Salinity: _____	Measured with: _____
Nitrate: _____	Measured with: _____
Sulfate: _____	Measured with: _____
Ferrous Iron: <u>0.2 mg/L</u>	Measured with: <u>HACH</u>
Other: <u>CO₂ = 4.2 mg/L</u>	<u>Mn = 0.3 mg/L</u>
<u>mg = 2.2 mg/L</u>	<u>Alk = 1.8 mg/L</u>

7 [] SAMPLE CONTAINERS (material, number, size): _____

8 [] ON-SITE SAMPLE TREATMENT:

[] Filtration: Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____

[] Preservatives added:
 Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____

9 [] CONTAINER HANDLING:

[] Container Sides Labeled
 [] Container Lids Taped
 [] Containers Placed in Ice Chest

10 [] OTHER COMMENTS: _____

SAMPLING LOCATION Upper Naknek _____
SAMPLING DATE(S) 8/15 - 8/25/94 _____

GROUND WATER SAMPLING RECORD - MONITORING WELL ESMW-14A
(number)

REASON FOR SAMPLING: ☒ Regular Sampling; ☐ Special Sampling;

DATE AND TIME OF SAMPLING: 9-23, 1994 10:34 a.m./p.m.

SAMPLE COLLECTED BY: KATH FEA of ES

WEATHER: _____

DATUM FOR WATER DEPTH MEASUREMENT (Describe): _____

MONITORING WELL CONDITION:

☐ LOCKED: ☒ UNLOCKED

WELL NUMBER (IS - IS NOT) APPARENT 64
STEEL CASING CONDITION IS: _____

INNER PVC CASING CONDITION IS: DN

WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT

☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR

☐ MONITORING WELL REQUIRED REPAIR (describe): _____

Check-off

1 ☒ EQUIPMENT CLEANED BEFORE USE WITH Alconox, Acetone, and Distilled H2O 5 gallons
Items Cleaned (List): All equipment used in sampling _____

2 ☒ PRODUCT DEPTH _____ FT. BELOW DATUM
Measured with: Oil/ Water Interface Probe _____

WATER DEPTH 6.5' below FT. BELOW DATUM
Measured with: Water Level Probe _____

3 ☐ WATER-CONDITION BEFORE WELL EVACUATION (Describe):
Appearance: Clear
Odor: _____
Other Comments: _____

4 ☐ WELL EVACUATION:
Method: Peristaltic
Volume Removed: 6 gallons
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors: _____
Other comments: _____

5 [] SAMPLE EXTRACTION METHOD:

[] Bailer made of: _____
 [] Pump, type: _____
 [] Other, describe: _____

Sample obtained is [] GRAB; [] COMPOSITE SAMPLE

6 [] ON-SITE MEASUREMENTS:

Temp: 4.5 °C Measured with: _____
 pH: 6.5 Measured with: _____
 Conductivity: _____ Measured with: _____
 Dissolved Oxygen: 0.7 mg/L Measured with: _____
 Redox Potential: 110 Measured with: _____
 Salinity: _____ Measured with: _____
 Nitrate: _____ Measured with: _____
 Sulfate: _____ Measured with: _____
 Ferrous Iron: 0.7 mg/L Measured with: _____
 Other: Alk = 34 mg/L Ca = 94 mg/L Mn = 5.1 mg/L

7 [] SAMPLE CONTAINERS (material, number, size): _____

8 [] ON-SITE SAMPLE TREATMENT:

[] Filtration: Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____

[] Preservatives added:
 Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____

9 [] CONTAINER HANDLING:

[] Container Sides Labeled
 [] Container Lids Taped
 [] Containers Placed in Ice Chest

10 [] OTHER COMMENTS: _____

SAMPLING LOCATION Upper Naknek _____
SAMPLING DATE(S) 8/15 - 8/25/94 _____

GROUND WATER SAMPLING RECORD - MONITORING WELL ESMW 13A

(number)

REASON FOR SAMPLING: [x] Regular Sampling, [] Special Sampling;

DATE AND TIME OF SAMPLING: 8/23/94 1994 8:30 a.m./p.m.

SAMPLE COLLECTED BY: KATH EPA of ES

WEATHER: _____

DATUM FOR WATER DEPTH MEASUREMENT (Describe): _____

MONITORING WELL CONDITION:

[] LOCKED:

[X] UNLOCKED

WELL NUMBER (IS - IS NOT) APPARENT

STEEL CASING CONDITION IS: OK

INNER PVC CASING CONDITION IS: OK

WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT

[] DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR

[] MONITORING WELL REQUIRED REPAIR (describe): _____

Check-off

1 [x]

EQUIPMENT CLEANED BEFORE USE WITH Alconox, Acetone, and Distilled H₂O Indicated

Items Cleaned (List): All equipment used in sampling _____

2 [x]

PRODUCT DEPTH _____ FT. BELOW DATUM

Measured with: Oil/ Water Interface Probe _____

WATER DEPTH 4.5 ft FT. BELOW DATUM

Measured with: Water Level Probe _____

3 []

WATER-CONDITION BEFORE WELL EVACUATION (Describe):

Appearance: Clear

Odor: _____

Other Comments: _____

4 []

WELL EVACUATION:

Method: Pump/line

Volume Removed: 5 gallons

Observations: Water (slightly - very) cloudy

Water level (rose - fell - no change)

Water odors: _____

Other comments: _____

5 [] SAMPLE EXTRACTION METHOD:

- [] Bailer made of: _____
 [] Pump, type: _____
 [] Other, describe: _____

Sample obtained is [] GRAB; [] COMPOSITE SAMPLE

6 [] ON-SITE MEASUREMENTS:

Temp: <u>4.0 °C</u>	Measured with: _____
pH: <u>6.5</u>	Measured with: _____
Conductivity: _____	Measured with: _____
Dissolved Oxygen: <u>0.1 mg/L</u>	Measured with: _____
Redox Potential: <u>+5</u>	Measured with: _____
Salinity: _____	Measured with: _____
Nitrate: _____	Measured with: _____
Sulfate: _____	Measured with: _____
Ferrous Iron: <u>70 mg/L</u>	Measured with: _____
Other: <u>Alk = 119 mg/L, Ca = 176 mg/L, Mn = 4.1 mg/L</u>	

7 [] SAMPLE CONTAINERS (material, number, size): _____

8 [] ON-SITE SAMPLE TREATMENT:

[] Filtration: Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____

[] Preservatives added: _____
 Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____

9 [] CONTAINER HANDLING:

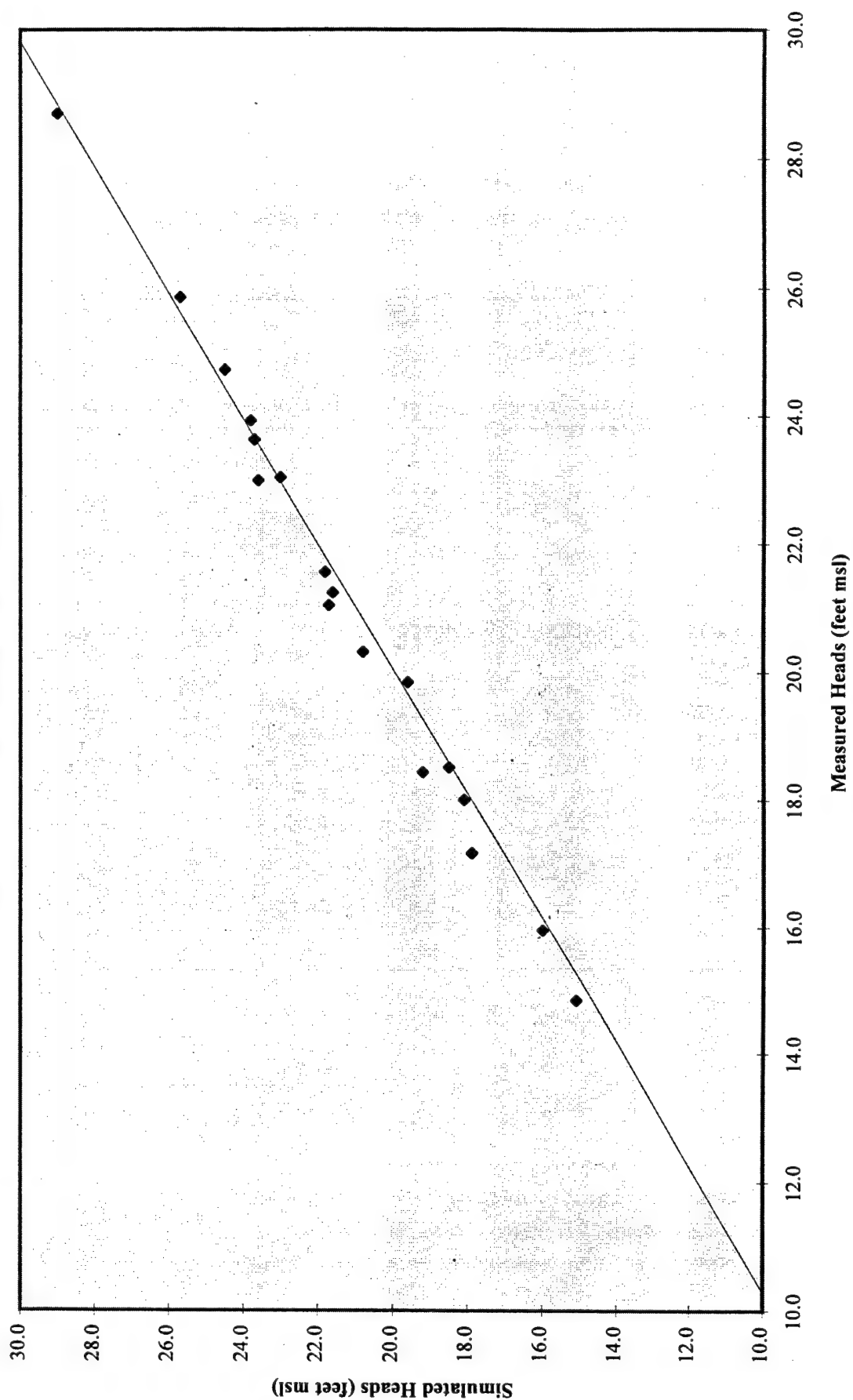
- [] Container Sides Labeled
 [] Container Lids Taped
 [] Containers Placed in Ice Chest

10 [] OTHER COMMENTS: _____

APPENDIX C

CALCULATIONS AND MODEL INPUT PARAMETERS

Measured Heads vs. Simulated Heads
Upper Naknek Site, King Salmon AFB



**Mean Error, Mean Average Error, and Root-Mean-Square Error
for the Calibrated Flow Model
Upper Naknek, King Salmon AFB**

Location	Actual Water Level (h _m) ^{a/}	Calibrated Water Level (h _s) ^{a/}	$h_m - h_s$	$\text{abs}(h_m - h_s)$	$(h_m - h_s)^2$
MW-89	28.7	29.0	0.30	0.30	0.09
MW-50	25.9	25.7	-0.16	0.16	0.03
ESMW-15	24.7	24.5	-0.23	0.23	0.05
500	23.0	23.6	0.60	0.60	0.36
MW-51	23.9	23.8	-0.14	0.14	0.02
MW-88	23.6	23.7	0.06	0.06	0.00
ESMW-8	23.1	23.0	-0.05	0.05	0.00
MW-52	21.1	21.7	0.65	0.65	0.42
ESMW-9	21.6	21.8	0.23	0.23	0.05
ESMW-10	21.3	21.6	0.35	0.35	0.12
ESMW-11	20.3	20.8	0.48	0.48	0.23
ESMW-12	19.9	19.6	-0.25	0.25	0.06
ESMW-13	18.4	19.2	0.76	0.76	0.58
ESMW-14	18.5	18.5	-0.02	0.02	0.00
MW-60	18.0	18.1	0.09	0.09	0.01
509	17.2	17.9	0.73	0.73	0.53
508	16.0	16.0	0.04	0.04	0.00
507	14.8	15.1	0.26	0.26	0.07
Total:	379.9	383.6	3.70	5.40	2.63
			ME ^{b/} =	0.21	
			MAE ^{c/} =	0.30	
			RMS ^{d/} =	0.38	

^{a/} Water levels are in feet mean-sea-level.

^{b/} ME = Mean Error = $1/n \times (h_m - h_s)$.

^{c/} MAE = Mean Average Error = $1/n \times |(h_m - h_s)|$.

^{d/} RMS = Root-Mean-Square (RMS) Error = $(1/n \times (h_m - h_s)^2)^{0.5}$.

Longitudinal Dispersivity Estimate
Upper Naknek Site
King Salmon AFB, Alaska

Assumptions:

A. The BTEX plume is sufficiently aligned along the longitudinal axis of the model grid and is relatively symmetric - so that a longitudinal moment may be calculated.

B. Longitudinal dispersivity is 1/10 of the distance from the approximate source of contamination to the longitudinal centroid.

Based on the September 1994 BTEX plume map at the Upper Naknek, the center of mass of the western most plume will be determined by calculating the longitudinal moment around monitoring well 51. Mass is computed by summing the concentrations of BTEX in an entire model row. Because two BTEX plumes exist at the site, the longitudinal dispersivity will be estimated for the western plume only (as centered around MW-51). To delineate between the two BTEX plumes, model grid column 11 acts as the assumed border.

<u>Row</u>	<u>Concentration^{a/}</u>	<u>Mass^{b/}</u>	<u>Distance from MW-51</u>	<u>Mass x Distance</u>
6	55	152623240	-175	-26709067000
7	300	832490400	-105	-87411492000
8	1000	2.775E+09	-35	-97123880000
9	1300	3.607E+09	35	1.26261E+11
10	600	1.665E+09	105	1.74823E+11
11	280	776991040	175	1.35973E+11
12	50	138748400	245	33993358000
13	25	69374200	315	21852873000
14	25	69374200	385	26709067000
15	15	41624520	455	18939156600
16	5	13874840	525	7284291000
Totals		1.014E+10		3.34592E+11

^{a/} Concentration of entire row in mg/L.

^{b/} Mass = (Concentration) x (70ft) x (70ft) x (20ft) x (28.316 liters per cu. foot) = mg.

The estimated longitudinal centroid of the plume:

$$3.34592E+11 / 1.014E+10 = 33 \text{ feet}$$

The estimated distance between the source to the centroid:

$$33 \text{ feet}$$

The estimated longitudinal dispersivity:

$$33 \times 0.1 = 3.3 \text{ feet}$$

Parameters Needed for the Estimation of a Recreation Coefficient:

(A) $Velocity = \frac{Ki}{n}$

K = Average hydraulic conductivity

i = Groundwater gradient

n = porosity

$K \sim 0.0251 \text{ ft/min or } 36.144 \text{ ft/day}$ (Section 3.3.2.2)

$i \sim 0.02$ at bluff area (Section 3.3.2.1)

$n \sim 0.25$ (Section 3.3.3.3)

Estimated $V = \frac{(0.0251 \text{ ft/min} \times 0.02)}{0.25} = 0.002 \text{ ft/min or } 2.89 \text{ ft/day}$

This V is for groundwater Velocity from the Bluff @ the Upper Nabeek to the Wetland. A better estimate for the wetland would be

Velocity (Wetland) $\sim 0.0006 \text{ ft/min or } 0.864 \text{ ft/day}$ (Section 3.3.1)

Based on the calibrated flow model [Nabeek A] in the PK2ip disk in Appendix D] the computer generated velocities in the area of the western plume source are approximately $1.0 \times 10^{-5} \text{ ft/s}$ which is 0.864 ft/day which is equivalent to the above calculated velocity.

Hence, as a conservative estimate of velocity (the lower the velocity, the lower the estimated recreation coefficient) velocity will be assumed as 0.864 ft/day .

Conservative
Velocity Estimate = 0.864 ft/day

(B) Retardation Coefficient:

$R = 1 + \frac{(Dk)(80)}{n} \sim 1.51$ (Table 5.2)

Recreation Coefficient Estimated with the Borden: Bedient Method.

Based on the work of Borden: Bedient (1984), an empirical equation for estimating a first-order decay coefficient was given on the conditions that site conditions (e.g., shallow sandy aquifer) are similar to those presented in the paper. Since the conditions of KSA are shallow aquifer with sandy matrix, it was assumed that the following equation could be used for an estimate of a first-order decay coefficient. Because the loss of BTEX in an aquifer is instantaneous (Borden: Bedient, 1984), the recreation coefficient is synonymous with the first-order decay coefficient.

$$K' = 2611 D_v^{0.79} \exp\left(\frac{-10.5B}{B + 1.04}\right)$$

K' = first-order-decay coefficient

B = Saturated thickness (m)

D_v = Vertical Dispersion Coefficient (m²/d)

This equation assumes that vertical dispersion was the only mechanism for vertical gas exchange (which is a conservative assumption).

$$D_v = (\alpha_v)(V_g) \quad (\text{assuming no molecular dispersion})$$

where;

D_v = Vertical Dispersion (L²/T)

α_v = Vertical Dispersivity Factor (L)

V_g = Groundwater Velocity (L/T)

α_v = Assume = 0.05 m (Borden: Bedient, 1984)

V_g = 0.263 m/day (Previous Page)

$$D_v = (0.05\text{m})(0.263\text{m/day}) = 0.01315\text{ m}^2/\text{day}$$

Assume that the average thickness of the aquifer is 20 feet (6.096 m):

$$K' = 2611 (.01315)^{0.79} \exp\left(\frac{-10.5(6.096)}{6.096 + 1.04}\right) \approx 0.0108 \text{ or } 0.011\%/\text{day}$$

Assume that the average thickness of the Aquifer is 15 feet (4.572 m):

$$K' = 2611 (0.01315)^{0.79} \exp\left(\frac{-10.5(4.572\text{m})}{4.572\text{m} + 1.04}\right) = 0.016\%/\text{day}$$

Recreation Coefficient Estimated with Rifaai et al (1988) 1st order Relationship

During the development of relationships in the Bioprocess model, hydrocarbon loss is ~~rate~~ instantaneous in the aquifer when an electron acceptor is present (i.e., oxygen). The following relationship was presented by Rifaai et al (1988) for simulated hydrocarbon loss in the aquifer:

$$H^t = H^{t-1} e^{-kt}$$

This is a simple 1st order relationship. This relationship does not distinguish between aerobic & anaerobic biodegradation since its values are based entirely on observed hydrocarbon loss. The first order phase of contaminant loss is shown on the next page.

H^t = Current hydrocarbon concentration (mg/L) (or the downgradient well concentration)
 H^{t-1} = Time zero hydrocarbon concentration (mg/L) (or the upgradient well concentration)
 k = Recreation coefficient (day⁻¹)
 t = Time from Time zero to current hydrocarbon concentration (day)

We will use the above equation to estimate recreation risks between 4 different monitoring wells to get a representative value over the areas of groundwater contamination.

Monitoring Well	BTEX Concentration (September 1994)	Distance Between Points in Direction of G.W. Flow	Travel Time Between Points	K
upgradient				
MW-51	673 mg/L	150 ft	173.6 days	0.0092
ESMW-10A	126 mg/L		(262.14) [†]	(0.006) [†]
W-2	3.82 mg/L	90 ft	104.2 days	0.034
ESMW-12A	4.96 mg/L	NA*	(457.34) [‡]	(0.022)
ESMW-13A	ND (below 0.001 mg/L for lowest detect limit)	130 ft	150.5 days	0.0106
downgradient			(227.3) [‡]	(0.007)

NA* The distance between these points is not applicable because the change in concentration between these points is not considered 1st order.

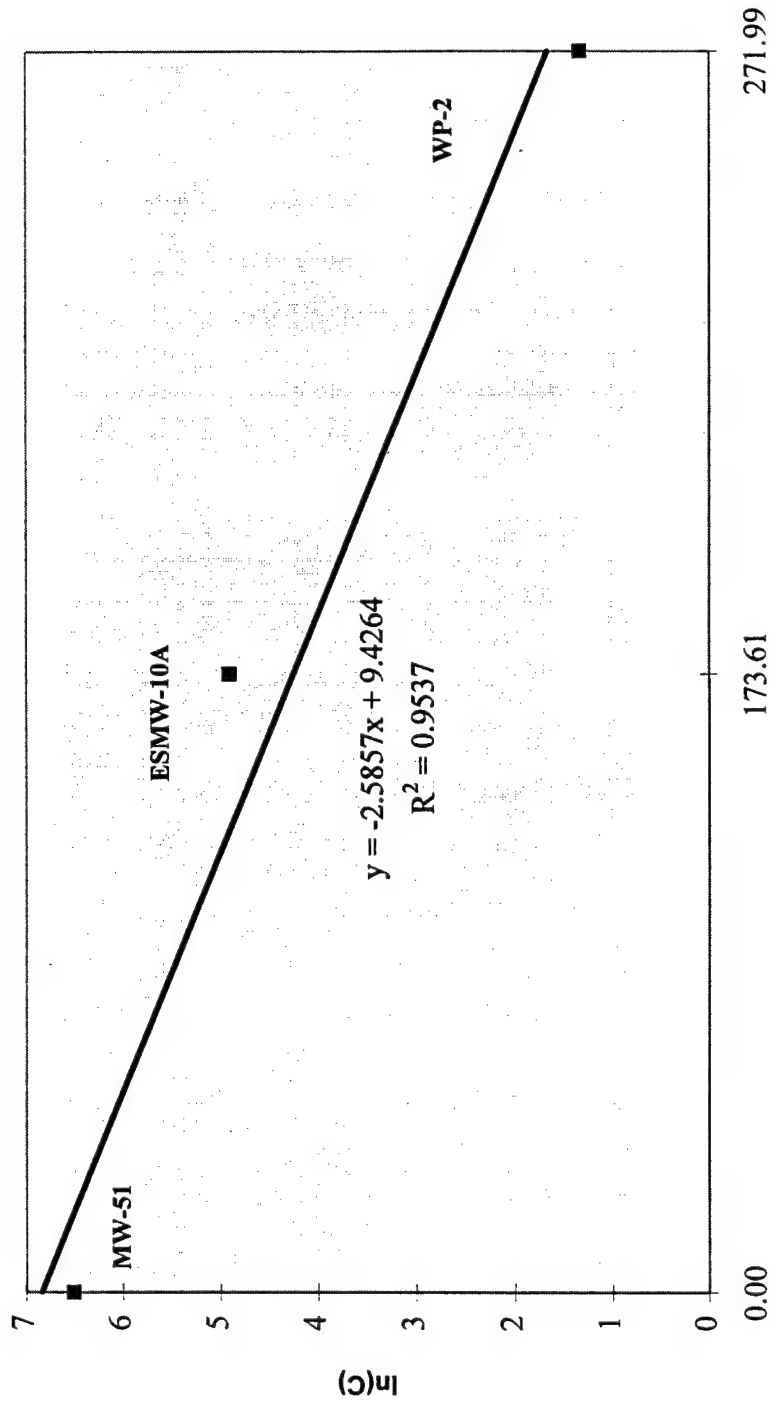
† Values in parentheses are groundwater velocities corrected for retardation (R=1.51)

‡ Assume a groundwater velocity of 0.864 ft/day (conservative)

+ Value in parentheses is K estimate using groundwater velocity corrected for retardation

Conclusion: The calculated first order recreation coefficients assume steady state conditions. Uncorrected values range from 0.0092 to 0.034 /day. Recreation coefficient values using corrected groundwater velocities (R=1.51) range from 0.006 to 0.023 /day.

Natural Log of Contaminant Concentration vs. Time
 To Illustrate 1st-Order Nature of Contaminant Loss
 of the Western Contaminant Plume
 at the Upper Naknek Site
 King Salmon Airport - Treatability Study
 King Salmon, Alaska



Time in Days for Contamination to Travel From MW-51
 (Assuming Ground Water Velocity of 0.864 ft/day)

**CALCULATION OF A FIRST-ORDER RATE CONSTANT
FOR THE WESTERN PLUME SOURCE AREA AT THE UPPER NAKNEK SITE
(NORMALIZED TO TRIMETHYLBENZENES)
KING SALMON AIRPORT - INTRINSIC REMEDIATION TS
KING SALMON, ALASKA**

Compound	MW-51 (0) Measured Concentration (µg/L)	ESMW-10A Measured Concentration (µg/L)	ESMW-10A Corrected Concentration ^{a/} (µg/L)	Percent Lost to Biodegradation	First Order Rate Constant Between MW-51 and ESMW-10A ^{b/} (day ⁻¹)
Benzene	3.43	14	36	-950	-0.014
Toluene	10	0.965	2	80	0.010
Ethylbenzene	108	20.7	53	51	0.004
p-Xylene	131	32.6	84	36	0.003
m-Xylene	274	34.7	89	68	0.007
o-Xylene	147	33.3	86	41	0.003
Total BTEX	673	136	350	48	0.004
1,3,5 Trimethylbenzene	74	16	16	78	0.015
1,2,4 Trimethylbenzene	101	39	39	61	0.009
1,2,3 Trimethylbenzene	62	37	37	42	0.005
Total TMBs	237	92	92	61	0.009

$k \sim 0.00025$ ft/s (near MW-51 and ESMW-10)

$dh/dl \sim 0.016$ (near MW-51 and ESMW-10)

$n_e = 0.25$

$R = 1.51$

$V_x = (k(dh/dl)R)/n_e = 1.06 \times 10^{-5}$ ft/s = 0.915 ft/day

$x_{A-B} = 150$ feet

$t_{A-B} = x_{A-B}/V_x = 163.9$ days

Conclusions on Reaction Coefficient estimations

The reaction coefficient was estimated using three methods. The first method used an empirical equation derived from another site (Borden & Bedient, 1980) that is applicable to other sites with similar conditions. The second method utilized a first-order relationship that is representative of hydrocarbon loss in an aquifer because hydrocarbon & oxygen loss are nearly instantaneous (Rifai & Bedient, 1988). The third method used TMB's as ~~non~~ recalcitrant tracers in JP-4 to correct for dispersion & retardation in the aquifer; to solve for corrected values of the reaction coefficient. The range of values obtained is shown below.

RANGE of Reaction Coefficient

Empirical Equation (Borden & Bedient, 1980)

0.0108 (20' sat. thickness)
0.016 (15' sat. thickness)

1st order Decay (Rifai et al., 1988)

(0.0092 - 0.034)

uncorrected for Retardation

(0.006 - 0.023)

corrected for retardation

TMB corrected 1st order Decay

Total BTEX = 0.004

Hence, the range of possible estimates for reaction rate is 0.004 to 0.034, of which, the value used for the model falls within (0.01). The TMB corrected 1st order Decay may be more representative of an anaerobic decay rate because TMB is suited for anaerobic biodegradation rate coefficients because it is biodegradable under aerobic.

References

- Rifai
Borden & Bedient, 1990, Comparison of Biodegradation Kinetics with an Dual-Phase Reaction Model For groundwater, Water Resources Research, Vol. 26, #4, 637-645
- Borden & Bedient, 1986, Transport of Dissolved Hydrocarbons influenced by Oxygen Limited Biodegradation - Theoretical Development: Water Resources Research, v. 22, no. 13, p. 1973-1982.
- Rifai, H.S., Bedient, P.B., Wilson, J.T., Miller, K.M., & Armstrong, J.M., 1988, Biodegradation modeling of an aviation fuel spill site. Journal of Env. Eng., v. 114, no. 5, p. 1007-1037.

Appendix C Calculation of Source Well Concentrations For Input into Model NaknekB

			Percent of Original Source Well Strength (from model Nakneka)						
Column	Row	Recharge Rate (cfs)	100%	90%	80%	70%	60%	50%	
			Values in columns below are in mg/L						
7	8	-5.00E-05	2.50E+01	2.25E+01	20	17.5	15	12.5	
7	9	-5.00E-05	4.00E+01	3.60E+01	32	28	24	20	
6	8	-5.00E-05	2.50E+01	2.25E+01	20	17.5	15	12.5	
7	7	-5.00E-05	1.50E+01	1.35E+01	12	10.5	9	7.5	
8	8	-5.00E-05	8.00E+01	7.20E+01	64	56	48	40	
9	8	-5.00E-05	8.00E+01	7.20E+01	64	56	48	40	
10	9	-5.00E-05	1.00E+02	9.00E+01	80	70	60	50	
13	9	-5.00E-05	1.10E+03	9.90E+02	880	770	660	550	
14	8	-5.00E-05	1.50E+01	1.35E+01	12	10.5	9	7.5	
14	9	-5.00E-05	4.00E+01	3.60E+01	32	28	24	20	
15	8	-5.00E-05	1.50E+01	1.35E+01	12	10.5	9	7.5	
15	9	-5.00E-05	1.50E+01	1.35E+01	12	10.5	9	7.5	
15	10	-5.00E-05	1.50E+01	1.35E+01	12	10.5	9	7.5	



Client _____

Job No. _____

Sheet _____ of _____

Subject KING SALMON AFB - UPPER NAKNEK MODELBy R.T.H.

Date _____

CONSTANT HEAD VALUES IN HEAD CELL

Checked _____

Rev. _____

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	29.5	29.5	29.6	29.8	30.0	30.0	30.3	30.3	30.5	30.5	30.6	30.8	31.0	31.1	31.2	31.4	31.5	31.6	0
3	0																			0
4	0																			0
5	0																			0
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24	0																			0
25	0																			0
26	0																			0
27	0																			0
28	0																			0
29	0	8.0	8.5	9.0	9.5	9.5	9.5	9.5	9.5	9.5	9.5	8.8	8.5	8.5	8.5	8.5	8.5	8.5	8.5	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

0 = INACTIVE CELL

HEAD VALUES IN FEET MSL



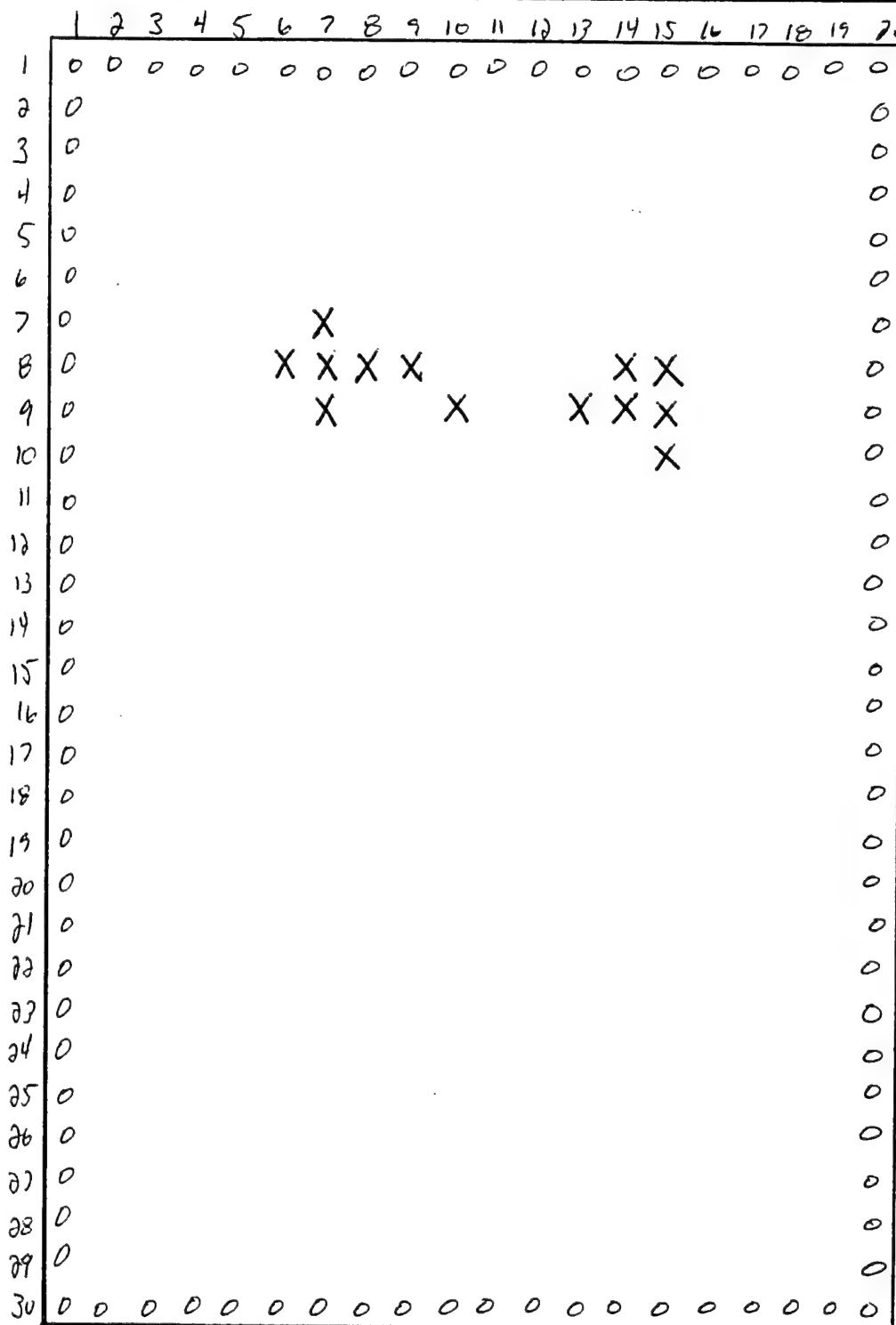


Client _____ Job No. _____
Subject KING SALMON AFB - UPPER WARNER MODEL By RTH
INJECTION WELL LOCATIONS Checked _____

Sheet _____ of _____

Date _____

Rev. _____



O = INACTIVE CELL

X = INJECTION WELL LOCATIONS



Client _____
 Subject KING SALMON AFB - WATER WAKNEK MODEL
CALIBRATED TRANSMISSIVITY GRID

Job No. _____
 By RTH
 Checked _____

Sheet _____ of _____
 Date _____
 Rev. _____

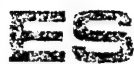
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2	0	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	0
3	0	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	0
4	0	B	B	B	B	C	C	C	B	B	B	B	B	D	D	D	D	D	D	0
5	0	E	E	F	B	G	G	G	B	B	B	B	B	D	D	D	D	D	D	0
6	0	H	H	H	B	C	C	C	B	B	B	B	B	D	D	D	D	D	D	0
7	0	H	H	H	B	I	C	C	C	C	B	B	B	B	B	B	B	B	B	0
8	0	F	F	F	C	C	J	J	J	J	B	B	B	B	B	B	B	B	B	0
9	0	B	B	B	B	I	I	I	I	I	I	I	I	I	I	I	I	I	I	0
10	0	F	E	E	E	E	E	E	E	E	E	E	I	K	K	K	K	K	K	0
11	0	L	L	L	L	L	L	L	M	M	E	E	E	B	B	B	B	B	B	0
12	0	L	L	L	L	L	L	L	L	H	H	E	B	B	B	B	B	B	B	0
13	0	L	L	L	L	L	L	L	E	E	E	E	E	E	E	E	E	E	E	0
14	0	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0
15	0	F	F	F	F	M	M	M	M	M	M	M	F	F	F	F	F	F	F	0
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17	0	M	M	M	M	M	M	M	M	M	F	F	F	F	F	F	F	F	F	0
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21	0	M	M	M	M	M	M	M	M	M	F	F	F	F	F	F	F	F	F	0
22	0	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	0
23	0	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	0
24	0	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	0
25	0	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	0
26	0	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	0
27	0	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	0
28	0	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	0
29	0	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0



0 = Inactive Cell
 A = $2.0 \times 10^{-2} \text{ ft}^2/\text{s}$
 B = $5.0 \times 10^{-3} \text{ ft}^2/\text{s}$
 C = $1.0 \times 10^{-3} \text{ ft}^2/\text{s}$
 D = $8.0 \times 10^{-3} \text{ ft}^2/\text{s}$
 E = $9.0 \times 10^{-3} \text{ ft}^2/\text{s}$

F = $7.0 \times 10^{-3} \text{ ft}^2/\text{s}$
 G = $8.0 \times 10^{-4} \text{ ft}^2/\text{s}$
 H = $1.0 \times 10^{-2} \text{ ft}^2/\text{s}$
 I = $2.0 \times 10^{-3} \text{ ft}^2/\text{s}$
 J = $9.0 \times 10^{-4} \text{ ft}^2/\text{s}$
 K = $4.0 \times 10^{-3} \text{ ft}^2/\text{s}$

L = $3.0 \times 10^{-2} \text{ ft}^2/\text{s}$
 M = $5.0 \times 10^{-2} \text{ ft}^2/\text{s}$



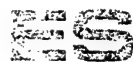
Client _____
Subject KING SALMON AFB - UPPER NAKNER MODEL
Starting DO Values (mg/L)

Job No. _____
By RTH
Checked _____

Sheet _____ of _____
Date _____
Rev. _____

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
2	11.7	11.1	11	10.9	10.9	10.5	10.6	11	11	11.3	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
3	11.7	11	11	10.5	10	9	9	8	8	10	10.2	11	11	11.7	11.7	11.7	11.7	11.7	11.7	11.7
4	11.7	11	10.5	10	8	5	4	2	.8	.8	.9	1	5	10	10.5	11.7	11.7	11.7	11.7	11.7
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15	11.7	11	9	5	1.5	.7	.4	.2	.2	.3	.3	.8	.6	.7	.8	.9	2	10.3	11.7	11.7
16	11.7	11	9	6	2	1	.5	.4	.2	.1	.2	.5	.6	.6	.8	.9	8	10.4	11.7	11.7
17	11.7	11	9	6	2	1	.7	.4	.3	.2	.1	.5	.6	.7	.9	1	9	11	11.7	11.7
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27	11.7	11	10	9	8	8	8	8	7	7	7	7	7	8	10.5	10.5	11	11.2	11.7	11.7
28	11.7	11	10	9	8	8	8	8	8	8	8	8	8	8	10.5	10.5	11	11.5	11.5	11.5
29	11.7	11	10	9	9	9	9	9	9	9	9	9	9	9	11	11	11	11	11	11
30	11.7	11	10	9	9	9	9	9	9	9	9	9	9	9	11	11	11	11	11	11





Client

Job No.

Sheet of

Subject KING SALMON AFB - UPPER NAKWEE MODEL

By

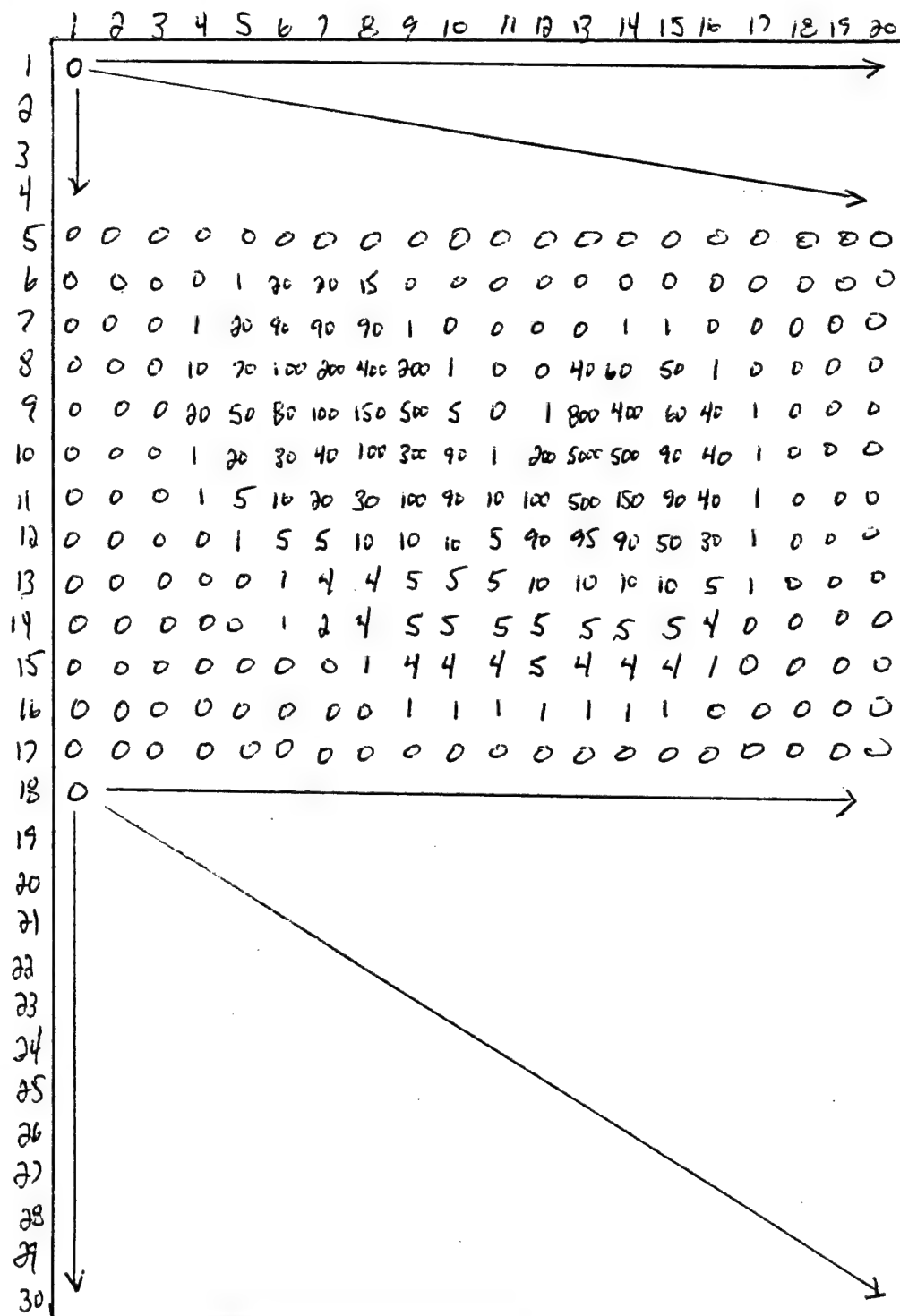
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Date

STARTING BTEX CONC. IN GROUNDWATER

Checked

Rev.



ALL CONCENTRATIONS ARE IN MICROGRAMS PER LITER (ug/L)

APPENDIX D

MODEL INPUT AND OUTPUT FILES

APPENDIX E

RESPONSE TO COMMENTS

PARSONS

Parsons Engineering Science, Inc. • A Unit of Parsons Infrastructure & Technology Group Inc.
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16 September 1999

Mr. Jerry Hansen
Technical Program Manager
AFCEE/ERT
3207 North Road, Bldg. 532
Brooks AFB, TX 78235-5363

Subject: Responses to AFCEE Comments on the Draft Intrinsic Remediation
Treatability Study for the Upper Naknek Site (SS-12), King Salmon Airport,
Alaska (Contract F41624-92-D-8036-0006)

Dear Mr. Hansen:

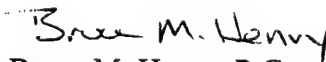
This letter provides responses to comments received on the Draft Intrinsic Remediation Treatability Study (TS) for the Upper Naknek Site (SS-12), King Salmon Airport, Alaska. This draft report was prepared by Parsons Engineering Science, Inc. (Parsons ES) for the Air Force Center for Environmental Excellence Technology Transfer Division (AFCEE/ERT) and Elmendorf Air Force Base (AFB).

The intent of the report was to summarize the results of a natural attenuation TS for the remediation of groundwater contaminated with fuel hydrocarbons at the Upper Naknek site. The draft report was submitted to AFCEE in April 1995. Comments on the draft report were received from AFCEE as reviewed by Mr. Jon Atkinson of HQ AFCEE/ERT, dated February 7, 1997. Responses to these comments were prepared by Parsons ES and are attached to this letter.

If you have any questions, have additional comments, or require additional information, please call me at (303) 831-8100.

Sincerely,

PARSONS ENGINEERING SCIENCE, INC.


Bruce M. Henry, P.G.
Project Manager

cc: File 722450.11000

SAES\WP\PROJECTS\722450\KING SALMON\7.DOC



**RESPONSE TO COMMENTS ON THE DRAFT TREATABILITY STUDY
IN SUPPORT OF INTRINSIC REMEDIATION (NATURAL ATTENUATION)
FOR THE UPPER NAKNEK SITE (SS-12),
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Response to AFCEE Comments dated 07 February 1997:

Comment 1) Page 2-6, Sec 2.1.2.3, Para 2: Removing soil cores from a split spoon and compositing them for VOC analysis is inconsistent with standard operating procedures outlined in our *Handbook for the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)* (Sep 1993). Section 2.1.3.3 of the Handbook specifies that soils to be analyzed for volatiles should be taken with a California (brass) ring or equivalent sampler. Compositing of VOC samples allows excessive degassing of target analytes. Suggest that the text state this fact here.

Parsons ES Response: *The soil sampling methodology employed at this site was (and is) consistent with early soil sampling efforts conducted under the Air Force Center for Environmental Excellence (AFCEE) innovative remedial technology program to field test the potential for natural attenuation at fuel contaminated sites. The IRP Handbook was not identified by either AFCEE or the United States Environmental Protection Agency (USEPA) (i.e., the National Risk Management Research Laboratory [NRML], formerly known as the Robert S. Kerr Environmental Research Laboratory) as a required or recommended technical guidance source for work conducted as part of the natural attenuation demonstration program.*

Although Parsons ES agrees that there is the potential for loss of volatile organic compound (VOC) mass using the soil compositing method specified in the text, Parsons ES does not agree with the recommendation to modify the text because: (1) soil VOC results are used primarily to delineate potential source areas, (2) soil VOC results are not factored quantitatively or qualitatively into the evaluation of natural attenuation of groundwater (i.e., the source term in the model was developed to simulate BTEX groundwater conditions, and was not defined by any soil-water leaching estimate using soil VOC data), and (3) the recommended remedial approach is driven by the objective to effectively address groundwater—not soil—fuel hydrocarbon contamination. Consequently, no modification to the text is deemed appropriate.

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Comment 2) Page 2-9, Sec 2.1.3.4: Recommend annotating the uniformity coefficient for the filter pack and appending the grain-size-distribution specifications to Appendix A.

Parsons ES Response: *Parsons ES will annotate the uniformity coefficient for the filter pack and append the grain-size-distribution specifications to Appendix A provided such information can be readily obtained from the vendor of Number 10-20 Colorado silica sand. However, If such information is not available for products purchased in the summer of 1994 (more than 5 years ago), no modification to the text will be made.*

Comment 3) Page 2-9, Sec 2.1.3.5, Para 1: Placing of screens at or above the land surface for three shallow wells is not justified because it allows precipitation and contaminants/particulate matter present only or predominately in surface water to enter the well. Placement of screens above the ground surface is not corroborated by data in Table 2.1 or unequivocally by the well completion diagrams in Appendix A (see comment 25).

Parsons ES Response: *Comment noted. As described in Section 2.1.3, Monitoring Well Installation, monitoring wells ESMW-9, ESMW-11, and ESMW-12 were installed in hand-augered bore holes to avoid damage to surrounding wetland areas. The well screens do extend above the ground surface for these wells. The text in Section 2.1.3 will be amended to indicate these wells were hand-installed as temporary monitoring wells. For temporary wells without a surface seal, adequate well development and purging prior to groundwater sampling is used to ensure that representative groundwater samples are collected.*

Comment 4) Page 2-10, Sec 2.2: Recommend adding a listing or table of wells that were sampled and the time period of sampling. Additionally, suggest adding a list of laboratory analytical parameters.

Parsons ES Response: *Two separate tables will be added to this section of the document to: (1) list the laboratory and field parameters targeted for measurement as part of the AFCEE demonstration program (Table 2.2), and (2) list the wells sampled during the 1994*

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demonstration effort, including a summary of the parameters measured at each well (Table 2.3). Parameter results are presented in various tables in Section 4 of this document.

Comment 5) Page 2-14, Sec 2.2.4.2: Recommend adding alkalinity to the discussion of field-measured parameters.

Parsons ES Response: *Alkalinity was measured in a temporary fixed-base lab and discussion of alkalinity is not within the context of Section 2.3.3 for Onsite Chemical Parameter Measurement.*

Comment 6) Page 2-14, Section 2.2.4.2, Line 3: Recommend deleting "or" that occurs after "field."

Parsons ES Response: *Agreed. This editorial correction will be made.*

Comment 7) Page 2-15, Sec 2.3: The statement that slug tests can be used for confined and unconfined aquifers that have a transmissivity of less than 7,000 ft²/day is only partially true, is misleading, and should be revised, based on the following considerations. The widely used Bouwer and Rice method is applicable primarily to unconfined aquifers. Typically, monitoring wells or piezometers are screened over only a portion of the unconfined aquifer. Consequently, slug tests in these wells measure hydraulic conductivity (K) for a relatively small vertical section of the aquifer because flow into the well screen is predominantly horizontal (see *Analysis and Evaluation of Pumping Test Data* (Kruseman and de Ridder, 1994, p. 246)). To measure transmissivity (K x aquifer thickness (b)) of a relatively thick unconfined aquifer using slug tests typically requires testing several wells screened over progressively deeper intervals (e.g., cluster or nested wells).

Parsons ES Response: *Parsons ES agrees with this recommendation, and will revise the referenced discussion as follows: "Slug tests were conducted to estimate the hydraulic conductivity of the shallow saturated zone at the Upper Naknek Site. Slug tests are single-well hydraulic tests used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. The hydraulic conductivity values determined from these slug tests (and the Bouwer and Rice methods, see below) are representative of a relatively small vertical section of the aquifer, because flow into*

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the well screen is predominantly horizontal. This approach is deemed adequate at this site given the known nature of the saturated zones underlying the site. Specifically, because the site is underlain by a relatively thin, shallow unconfined aquifer, the hydraulic conductivity values determined from most of the shallow groundwater wells will be representative of this zone." No further text modification is required (i.e., all subsequent discussions refer to hydraulic conductivity, rather than transmissivity, measurements).

Comment 8) Page 2-16, Sec 2.4: Suggest the text state the appropriate order of the survey (e.g., third order).

Parsons ES Response: *Parsons ES will revise the text to specify the appropriate order of the survey, as suggested: "After the field work described herein was concluded, a third order survey of all new monitoring well locations and elevations was completed by a professional land surveyor."*

Comment 9) Page 3-1, Sec. 3.1.2, Line 6: Recommend deleting the superfluous "on."

Parsons ES Response: *Agreed. The text will be changed as recommended.*

Comment 10) Page 3-4, Figure 3.1: Suggest adding to this cross section a horizontal bar scale or approximate scale specification.

Parsons ES Response: *Agreed. A horizontal scale should be added to Figure 3.1 as suggested, but was not included with the referenced figure.*

Comment 11) Page 3-10, Sec 3.3.2.1, Para 2, Line 10: Recommend changing "surfacewaters" to surface waters."

Parsons ES Response: *Agreed. The text will be changed as recommended.*

Comment 12) Page 4-11, Sec 4.3.1.1, Para 1: Here, and throughout Section 4, suggest reducing the number of significant figures for reporting analytical results

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from four to three to better reflect the accuracy and precision of the measurements (e.g., 5,261 µg/L to 5,260 µg/L).

Parsons ES Response: *Agreed. This technical modification will be made throughout the text of Section 4.*

Comment 13) Page 4-12, Sec 4.3.2: Recommend numbering chemical reactions to facilitate referencing them.

Parsons ES Response: *Parsons ES disagrees with this comment, because (1) discussions related to balanced chemical reactions are limited in the text, and (2) such cross-referencing may serve to confuse the lay reader. One of the primary objectives of the AFCEE demonstration program for natural attenuation of fuel contamination in groundwater is to educate Air Force personnel and the regulatory community. Use of a chemical reaction numbering system, which could prompt paging backward in the text to find the original reaction referenced, would likely make the discussions about geochemistry burdensome and not user-friendly.*

Comment 14) Page 4-12, Sec 4.3.2:

- a. Recommend adding a summary table of major cation and anion analyses or adding these data to Table 4.4.

Parsons ES Response: *Parsons ES recognizes the value of collecting and presenting major cation and anion groundwater results in terms of better characterizing groundwater quality. However, the focus of this treatability study, and the AFCEE demonstration program for natural attenuation of fuel contamination in groundwater, is primarily on evaluating geochemical indicators that are directly relevant to documenting biodegradation and that may be unique to a traditional groundwater characterization effort.*

The parameters listed in Table 4.4 are specifically required by the Technical Protocol to assess the potential for fuel biodegradation. Although other parameters (e.g., sodium, calcium, chloride) may be important measurements to establish general groundwater chemistry (and verify data quality), only

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those analytes that are tied to developing field-scale evidence of biodegradation are targeted by the sampling and analysis efforts. Consequently, the elemental constituent results referenced in this comment will not be incorporated into the body of the report.

- b. Suggest adding a concise discussion of accuracy of the major cation and anion analyses utilizing the cation-anion balance method. As a rule-of-thumb, a percent difference exceeding 10 for low-salinity water suggests a data quality problem. For 24 analyses of 21 KSMW series and three KSWP series well, eight analyses fail this quality assurance check (see attached summary sheets).

Parsons ES Response: *The use of a cation-anion balance method to check for data quality problems is an excellent recommendation. The reviewer clearly understands the importance of establishing basic water chemistry parameters before evaluating the potential for localized micro-environment changes. Although much of the elemental constituent data produced by the USEPA during the 1994 sampling program exceeded the intended scope of the demonstration effort (and was, therefore, not addressed by planned quality assurance requirements), Parsons ES recognizes the value of the data check proposed by the reviewer.*

However, the major geochemical indicators of intrinsic remediation are the depletion of oxygen, nitrate, and sulfate and the generation of ferrous iron, manganese, methane, and carbon dioxide. Trend changes in these geochemical indicators represents actual use of electron acceptors or generation of biodegradation byproducts directly related to the biodegradation of fuel hydrocarbons (e.g., methane and CO₂). Parameters such as electrical conductivity and alkalinity are affected by intrinsic remediation, but they are not an integral part (e.g., electron acceptor or metabolic byproduct) of the biodegradation reaction. Therefore, while EC and alkalinity are part of an overall argument for intrinsic remediation based on geochemical trends; they offer little by themselves to support intrinsic remediation. Therefore, Parsons requests that an in-depth analysis of EC/TDS trends and their affect on alkalinity readings not be performed, as the argument for intrinsic remediation will not be weakened by omitting this analysis.

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Comment 15) Page 4-12, Sec 4.3.2, Sent 5: In the list of electron acceptors, "ferrous iron" should be replaced by "ferric iron."

Parsons ES Response: *Agreed. The text will be changed as indicated.*

Comment 16) Page 4-15, Table 4-4: This table contains field geochemical data for 27 wells; however, Appendix B contains field data for at least 47 wells. Recommend all applicable data be placed in this table.

Parsons ES Response: *The reviewer appears to be referencing field geochemical data collected by the USEPA at the Fire Training Area #1 (FT01), which is located east of Site SS-12 (see Figure 1.3). The "additional" geochemical data included in Appendix B are from wells located in this area, which is not part of subject study site (see well maps included in Appendix B). Parsons ES included all data sheets provided by USEPA as part of the King Salmon Airport sampling effort in Appendix B, and did not attempt to "re-write" the data summary sheets that included these off-site sampling results. However, inclusion of these data into the body of the text would be inappropriate. Only the sampling results from the wells listed to be a part of the 1994 AFCEE-sponsored sampling event (see Section 2.2.1) are presented and discussed in the report.*

Comment 17) Page 4-17, Sec 4.3.2.1, Para 3: For the chemical reaction, suggest adding valences for ammonium and bicarbonate ions.

Parsons ES Response: *Agreed. This addition will be made.*

Comment 18) Page 5-8, Sec 5.4.1, Para 1: Recommend stating the range in recharge from precipitation used in the model and relating this range to the annual precipitation.

Parsons ES Response: *The model was not actually calibrated by assuming a specific rate of recharge from precipitation and incorporating such recharge areas into the model using "injection wells" or constant-head cells at locations other than the model boundaries (see Appendix C). Rather, the model setup for this site assumed that the hydraulic conductivity at certain cell locations (i.e., those possibly influenced by wetland recharge) could be varied within*

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a reasonable range from observed conditions to calibrate overall site flow conditions.

Recharge from the wetland area was incorporated into the flow model as cells characterized by some of the highest hydraulic conductivity values (i.e., 5.0×10^{-2} ft/sec). The text merely implies that the change in hydraulic conductivity at these locations, relative to those cells located immediately upgradient, can be qualitatively attributed to recharge from precipitation. This calibration step resulted in a water table surface that closely resembled measured field conditions, and an overall excellent hydraulic mass balance. Consequently, although it may be possible to "back-calculate" an estimate of the recharge rate that would be required to support the calibrated hydraulic conductivity values at certain cell locations, such an approximation would not improve the model setup discussion and/or clarify model assumptions.

Comment 19) Page 5-13 and 5-16, Sec 5.4.2, Para 4: Recommend that the text state why one year was chosen as the time period to achieve a modeled plume that approximated the existing plume.

Parsons ES Response: *The text already includes an explanation on page 5-12 as to why the one-year simulation period was selected as the calibration period. In summary, the report concludes that the existing plume (as measured in 1994) represents the maximum likely extent of contamination. Consequently, rather than attempt to calibrate the model to conditions that may have caused the existing plume (i.e., from time 0), the model was used to establish the maximum extent of contamination during the first time step (1 year). Stabilization of the simulated plume, to conditions that closely match 1994 measured conditions, was predicted within 4 years.*

Comment 20) Page 6-5, Sec 6.2.3, Line 7: To correct subject-verb agreement, recommend changing "have" to "has."

Parsons ES Response: *Agreed. The text will be changed as recommended.*

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Comment 21) Page 6-22, Table 6.3: Suggest reporting total BTEX to three significant figures (136 µg/L), not four, to improve consistency with other reported values and to better reflect accuracy and precision.

Parsons ES Response: *Agreed. This correction will be made at the referenced location.*

Comment 22) Page 7-3, Table 7.1: Suggest adding alkalinity because it is an indicator of natural attenuation, a good general water-quality parameter (major anion), and because it appears in Table 2-1 of the *Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater*. Additionally, suggest adding major anions chloride and sulfate and major cations (Ca, Mg, Na, K) because they define aqueous geochemistry and allow assessment of biodegradation impacts on general groundwater geochemistry.

Parsons ES Response: *Alkalinity will be added to Table 7.1, in keeping with the requirements of the Technical Protocol. However, although Parsons ES recognizes the value of including other major cation/anion analyses to the recommended long-term monitoring protocol, such significant changes to the current natural attenuation monitoring and data analysis requirements need to be discussed with AFC EE and the USEPA before modifying site-specific reports. Consequently, Parsons ES will pass along these recommendations, for future discussion.*

Comment 23) Page 7-8, Figure 7.2: Recommend that a well casing vent hole or a ventilated well cap be depicted in conformance with Section 2.1.2.1 of our *Handbook for the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)* (Sep 1993).

Parsons ES Response: *Parsons ES will modify the referenced figure as recommended. However, please note that the proposed POC and LTM monitoring well completion diagram is provided in this report for general schematic purposes only. The Base will be responsible for installing and maintaining these monitoring points. The specific installation requirements and completion details will be determined by the implementing contractor in accordance with Base-specific program requirements.*

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Comment 24) Page 8-4, Sec 8, Para 1, Line 3: To improve readability, suggest inserting "of" after "continuity."

Parsons ES Response: *Agreed. The text will be changed as suggested.*

Comment 25) Appendix A: For monitoring wells ESMW-9A, -11A, and -12A, the top screen is shown relatively well below the ground surface on the well construction diagram. However, the stated total depth of each monitoring point is less than the annotated screen length. These discrepancies should be resolved.

Parsons ES Response: *Comment noted. As described in Section 2.1.3, Monitoring Well Installation, monitoring wells ESMW-9, ESMW-11, and ESMW-12 were installed in hand-augered bore holes to avoid damage to surrounding wetland areas. The well screens do extend above the ground surface for these wells. The text in Section 2.1.3 will be amended to indicate these wells were hand-installed as temporary monitoring wells. The well construction diagrams are standard schematic forms and as such are not drawn to scale.*

Comment 26) Appendix A: Recommend that field (data logger) water-level data for the slug tests be appended. This will allow independent evaluation of the aquifer test data.

Parsons ES Response: *Agreed. If the slug test data are available, they will be included as a separate diskette or listing in the appendix.*

APPENDIX F

FINAL ADDENDUM TO THE INTRINSIC REMEDIATION TREATABILITY STUDY FOR THE UPPER NAKNEK SITE (SS-12), KING SALMON AIRPORT, KING SALMON, ALASKA

FINAL

**ADDENDUM TO THE INTRINSIC REMEDIATION TREATABILITY STUDY
FOR THE UPPER NAKNEK SITE (SS-12)**

at

**KING SALMON AIRPORT
KING SALMON, ALASKA**

October 1999

Prepared for:

**AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS**

and

**ELMENDORF AIR FORCE BASE
ANCHORAGE, ALASKA**

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LIST OF ACRONYMS AND ABBREVIATIONS

$\mu\text{g/L}$	micrograms per liter
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
AST	aboveground storage tank
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
CaCO_3	calcium carbonate
CAHs	chlorinated aliphatic hydrocarbons
CO_2	carbon dioxide
DO	dissolved oxygen
ES	Engineering Science, Inc. (now known as Parsons Engineering Science, Inc.)
Fe^{2+}	ferrous iron
Fe^{3+}	ferric iron
ft	feet
ft/day	feet per day
ft/ft	foot per foot
ft/yr	feet per year
IRP	Installation Restoration Program
KSA	King Salmon Airport
LNAPL	light non-aqueous phase liquid
LTM	long-term monitoring
MCL	maximum contaminant level
mg/L	milligrams per liter
MTBE	methyl tert-butyl ether
mV	millivolts
NRMRL	National Risk Management Research Laboratory
ORP	oxidation-reduction potential
Parsons ES	Parsons Engineering Science, Inc.
POC	point of compliance
POL	petroleum, oil, and lubricant
redox	reduction-oxidation
TC	total carbon
TIC	total inorganic carbon
TMBs	trimethylbenzenes
TOC	total organic carbon
TS	treatability study
USEPA	US Environmental Protection Agency
UST	underground storage tank
VFAs	phenols and aliphatic/aromatic acids
VOCs	volatile organic compounds

1.0 INTRODUCTION

This report was prepared for the Air Force Center for Environmental Excellence (AFCEE) and Elmendorf Air Force Base (AFB) by Parsons Engineering Science, Inc. (Parsons ES) as an addendum to the *Treatability Study (TS) in Support of Intrinsic Remediation (Natural Attenuation) for the Upper Naknek Site (SS-12), King Salmon Airport (KSA), King Salmon, Alaska* (Parsons ES, 1995). The TS was conducted to evaluate the use of intrinsic remediation with long-term monitoring (LTM) to address fuel-hydrocarbon-contaminated groundwater at the Upper Naknek Site (SS-12). This addendum summarizes the results of two LTM sampling events conducted in July 1995 and September 1998 by researchers from the US Environmental Protection Agency (USEPA) National Risk Management Research Laboratory (NRML) Subsurface Protection Division.

The main emphasis of this summary is to evaluate changes in dissolved benzene, toluene, ethylbenzene, and xylene (BTEX) concentrations, the extent of the BTEX plume, and the effectiveness of attenuation mechanisms through time. Results, calculations, and model predictions presented in the 1995 TS (Parsons ES, 1995) are used as the basis for comparison. Data collected in August 1989, by CH₂M Hill as part of the facility-wide Installation Restoration Program (IRP) (CH₂M Hill, 1989 and 1990), are also used where available to evaluate temporal trends. Data collected in July 1995 and September 1998 are presented in Attachments A and B, respectively.

1.1 Relevant Site Background and Features

KSA is situated on a 216-acre site located on the upper, northwestern side of the Alaskan Peninsula. Anchorage, Alaska is 280 miles to the northeast. KSA is located on the northern bank of the Naknek River, facing Bristol Bay. The closest communities are the small towns of King Salmon, located adjacent to the northern boundary of KSA, and Naknek and South Naknek, located approximately 13 miles west-northwest of KSA along the Naknek River. KSA is accessible only by air or water.

The Upper and Lower Naknek Sites (collectively referred to as Site SS-12) are located on the northern bank of the Naknek River, approximately 0.7 mile west of the town of King Salmon, Alaska. The Upper Naknek Site is situated in the Nushagak-Bristol Bay Lowland, an area with little vertical relief. The general grade of the land surface is modest as it slopes toward the Naknek River, which is approximately 1,500 feet to the south. A natural wetland and a stretch of subarctic forest separate the Upper and Lower Naknek Sites. The Upper Naknek Site is situated on a manmade bluff overlooking the wetland. This bluff is approximately 15 feet in height and runs east/west along the southern border of the Upper Naknek Site. At the base of the bluff, groundwater is present at or near the land surface, defining the beginning of the wetland. The wetland is an intermediate recharge or discharge point for groundwater in the surface aquifer (A-Aquifer). The Naknek River is the ultimate discharge point for groundwater in the surface aquifer. A north/south road connects the Upper Naknek Site with the Lower Naknek Site. A culvert beneath the north/south road is a flow path between the upper Naknek wetland and wetland terrain to the east.

Site SS-12 was a petroleum, oil, and lubricants (POL) tank farm (primarily JP-4 jet fuel) comprised of numerous underground storage tanks (USTs) and aboveground storage tanks (ASTs). A drum shredding operation located in the central portion of the Upper Naknek Site contains shredded steel barrels stacked in a fenced pile extending as much as 10 feet below ground surface (bgs) and as high as 30 feet above the ground surface. A french drain is located in the lower central part of the Upper Naknek Site. The surface of this french drain consists of medium gravel extending down the sideslope of the east/west bluff and approximately 20 feet into the wetland area. Additionally, a north/south road connects the Upper Naknek Site with the Lower Naknek Site. A culvert beneath the north/south road is a flow path between the upper Naknek wetland and wetland terrain to the east. A site layout of the Upper Naknek Site is shown in Figure 1.

Fuel was supplied to Site SS-12 by barge, where it was unloaded via pipeline into the tanks and stored until needed. Available information is limited as to locations of excavated USTs or currently operating USTs at the site. However, a previous report (EMCON, 1994) indicates that ASTs at the Upper Naknek Site have been removed and the cumulative count of USTs having existed at the site includes: 2 25,000-gallon "Operation USTs," 24 50,000-gallon USTs, and 24 25,000-gallon USTs. Three 25,000-barrel ASTs and one 11,900-barrel AST were also located at the Lower Naknek Site.

1.2 Summary of Site Characterization Data

Site SS-12 has undergone previous investigations related to the facility-wide IRP. Early evidence of contamination was observed as visible sheens of hydrocarbons on nearby surface waters (Engineering-Science, Inc.[ES], 1985). Site investigations performed by CH₂M Hill from 1987 to 1990 (CH₂M Hill, 1989 and 1990) confirmed the presence of concentrations of benzene in groundwater that exceeded the federal maximum contaminant level (MCL) for benzene of 5 micrograms per liter (µg/L). In 1992, light non-aqueous phase liquid (LNAPL) was reported to be entering the wetlands immediately to the south of the site. In response, in 1993, a french drain and lateral trench were constructed at the site to stop migration of this contamination into the Naknek River. Surface water sheens resembling hydrocarbon contamination below the french drain have been observed in the wetland during subsequent site investigations.

Parsons ES, in conjunction with researchers from the USEPA NRML Subsurface Protection Division, was retained by AFCEE to conduct site characterization and groundwater modeling activities in support of intrinsic remediation with long-term monitoring (LTM). The two primary objectives of the initial activities completed by this team were to (1) determine whether naturally occurring attenuation processes for fuel hydrocarbons were occurring in groundwater at the site, and, if so, (2) investigate if these processes would be sufficient to minimize the expansion of the fuel hydrocarbon plume to ensure that federal- and state-specified groundwater protection standards would be met at a downgradient point of compliance (POC).

Site characterization activities in support of intrinsic remediation, which were completed in September 1994, included soil borehole drilling with soil sample collection and analysis, monitoring well installation, and sampling and analysis of

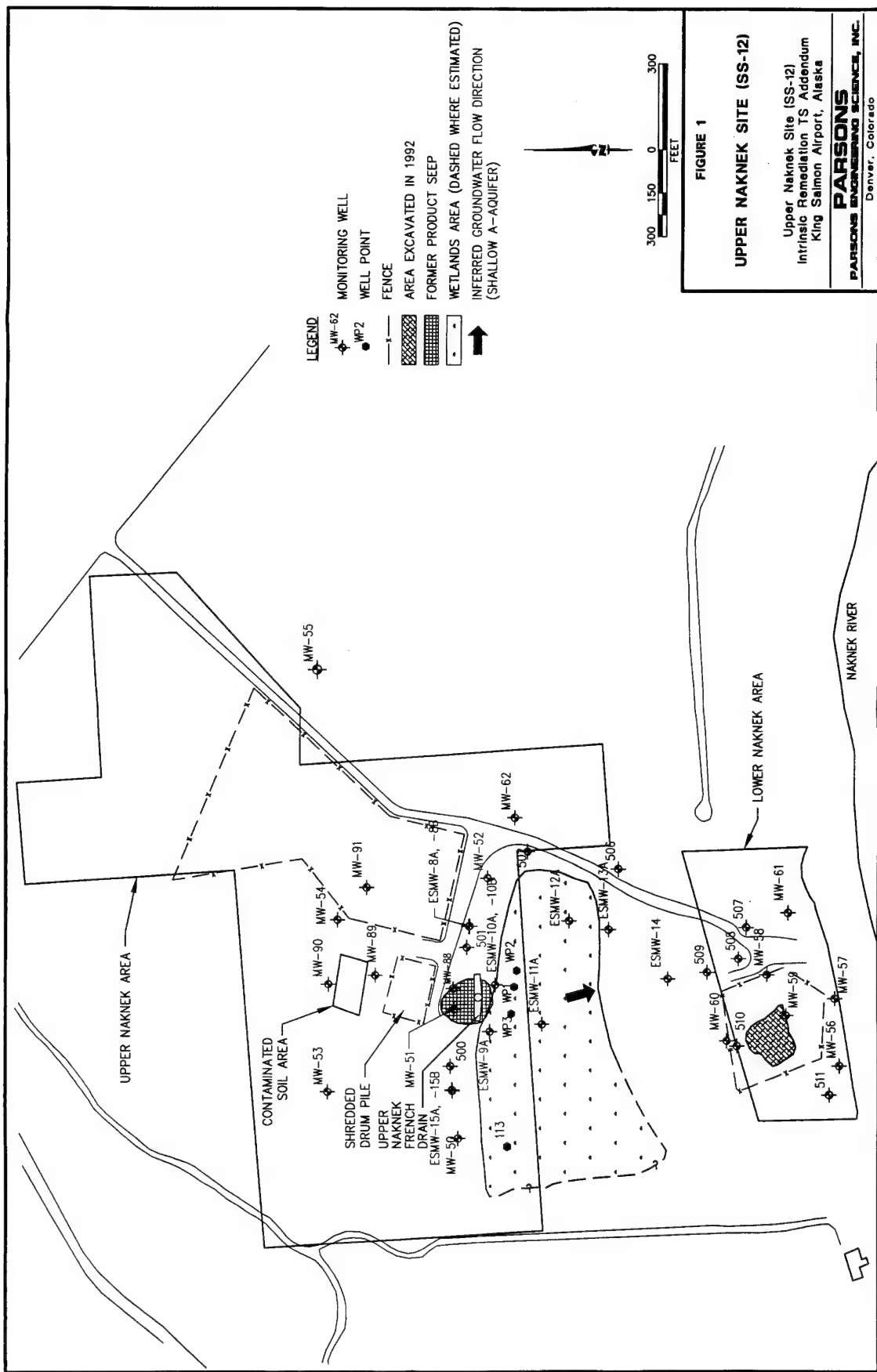


FIGURE 1

UPPER NAKNEK SITE (SS-12)

Upper Naknek Site (SS-12)
Intrinsic Remediation TS Addendum
King Salmon Airport, Alaska

PARSONS
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

groundwater from newly installed and existing monitoring wells. Site-specific data were used to develop a fate and transport model for the site using Bioplume II model code and to conduct a preliminary exposure pathways analysis. The Bioplume II model was used to simulate the movement of dissolved BTEX in the shallow saturated zone (A-Aquifer) under the influence of advection, dispersion, sorption, and biodegradation. These model results, which are presented in the TS (Parsons ES, 1995), were used to determine if intrinsic remediation with LTM would be an appropriate and defensible remedial option for contaminated groundwater at Site SS-12.

Field data collected in September 1994 suggested that the dissolved BTEX plume at the Upper Naknek Site was approximately 850 feet long by 900 feet wide. The downgradient extent of the BTEX contamination underlay the wetland area directly south of the Upper Naknek Site. Where detected in 1994, total BTEX concentrations ranged from less than 1 µg/L to 5,260 µg/L. These groundwater analytical results for BTEX compounds are similar to those obtained and reported prior to 1994. Additionally, the data collected as part of the 1994 TS indicated that aerobic biodegradation and anaerobic degradation via ferric iron reduction and methanogenesis is occurring in shallow groundwater at the site.

1.3 Overview of Proposed Remedial Approach

Based on the results of a comparative analysis of two potential remedial alternatives, the 1995 TS (Parsons ES, 1995) concluded that source identification, intrinsic remediation, LTM, institutional controls, and contingent predictive risk assessment would be an appropriate and defensible approach to address BTEX-contaminated groundwater at Site SS-12. The results of the fate and transport model indicated that the dissolved BTEX had almost achieved its maximum, stable conditions, and that existing attenuation mechanisms should be sufficient to prevent significant contaminant concentrations from impacting the deeper B-Aquifer and downgradient wetland areas. The recommended remedial option included a predictive risk assessment to evaluate whether the hydrocarbon concentrations that could migrate to wetland areas would pose an unacceptable threat to ecological receptors. The TS report concluded with a recommendation for continued LTM using five existing onsite wells, to verify plume stability and the ongoing effectiveness of natural attenuation processes.

However, the Air Force was concerned that, without engineered source reduction, intrinsic remediation alone might not be sufficient to ensure protection of human health and the environment. This concern was based on the presence of mobile and residual LNAPL in the subsurface, as well as the proximity of the culvert, which could serve as a potential exposure point for groundwater contaminants discharging to surface water. Consequently, the Air Force recommended that an engineered source removal, such as bioslurping, be implemented at Site SS-12 (in conjunction with intrinsic remediation, LTM, and institutional controls). In the fall of 1997, a bioslurping pilot test was conducted at Site SS-12. Unfortunately, the results of this pilot test indicated that bioslurping would not be an effective technology to remediate mobile and/or residual LNAPL at the site, primarily due to seasonal fluctuations in groundwater elevation and LNAPL thickness. Currently, intrinsic remediation with LTM are the only remedial

approaches being relied upon to reduce both source and dissolved contaminant mass at the site.

2.0 1995 AND 1998 MONITORING RESULTS

In July 1995 and September 1998, researchers from the USEPA NRMRL Subsurface Protection Division measured groundwater elevation levels and collected groundwater samples for field and fixed-base laboratory analysis. In July 1995, groundwater samples were collected from 20 existing site wells (i.e., ESMW-8A, -8B, -10A, -10B, -12A, -14A, -15A, -15B, MW-50, MW-51, MW-52, MW-88, MW-89, MW-90, 500, 501, 506, WP-1, WP-2, and WP-3). These collected groundwater samples were analyzed in the field for dissolved oxygen (DO), temperature, pH, reduction-oxidation (redox) potential (ORP), alkalinity, carbon dioxide (CO₂), sulfate, sulfide, and ferrous iron (Fe²⁺). Additional sample volume was analyzed, using fixed-base techniques, for BTEX, trimethylbenzenes (TMBs), naphthalene, total fuel carbon, chlorinated aliphatic hydrocarbons (CAHs), chlorobenzenes, phenols and aliphatic/aromatic acids (VFAs), methane, sulfate, chlorides, nitrate+nitrite, total organic carbon (TOC), total carbon (TC), total inorganic carbon (TIC), and conductivity. The analytical methods used during this LTM sampling event are presented in Table 1A. Copies of laboratory results and field analytical notes are provided in Attachment A.

In September 1998, the LTM sampling event was limited to 7 existing onsite wells (i.e., ESMW-8A, -8B, -15A, -15B, MW-51, MW-88, and 500). These collected groundwater samples were analyzed in the field for DO, temperature, pH, ORP, alkalinity, and CO₂. Additional sample volume was collected for offsite, fixed-based analysis of BTEX, TMBs, naphthalene, total fuel carbon, methyl tert-butyl ether (MTBE), CAHs, chlorobenzenes, methane, ethene, ethane, ammonia, sulfate, chlorides, nitrate+nitrite, and TOC. The analytical methods used during this LTM sampling event are presented in Table 1B. Copies of laboratory results and field analytical notes are provided in Attachment B.

2.1 Flow Direction and Gradient

Prior to purging and sampling each monitoring well, groundwater levels were measured. Depth to groundwater was measured in all but one of the sampled wells in July 1995 and in all wells sampled in September 1998. Table 2 lists groundwater elevations for the September 1994, July 1995, and September 1998 sampling events. Groundwater elevation contour maps based on the results of the September 1994, July 1995, and September 1998 sampling events are presented on Figure 2. Because some wells are paired and screened in deeper aquifer intervals, only wells reflecting the shallower groundwater elevation (i.e., A-Aquifer) were used to construct contour intervals on Figure 2. The predominant direction of shallow groundwater flow at Site SS-12 is to the south/southeast toward the Naknek River. Groundwater flow at the site also appears to be influenced by the french drain system.

Groundwater elevations measured in upper aquifer in July 1995 and September 1998 were an average of 0.4 foot (ft) and 2.1 ft lower, respectively, than elevations measured in September 1994. In July 1995, changes in groundwater elevations ranged from an increase of 3.7 ft (well 500) to a decrease of 1.9 ft (ESMW-10A) compared to

TABLE 1A
SUMMARY OF GROUNDWATER ANALYTICAL METHODS
JULY 1995
UPPER NAKNEK SITE (SS-12)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Analyte ^{a/}	Method	Field (F) or Fixed-Base Laboratory (L)
Oxidation/Reduction Potential	Direct Reading Meter	F
Dissolved Oxygen	Direct Reading Meter	F
Temperature	Direct Reading Meter	F
pH	Direct Reading Meter	F
Ferrous Iron (Fe ²⁺)	Colorimetric, Hach Method 8146 or equivalent	F
Hydrogen Sulfide	Colorimetric, Hach Method 8131 or equivalent	F
Sulfate	Colorimetric, Hach Method 8051 or equivalent	F
Carbon Dioxide	Titrimetric, Hach Method 1436-01 or equivalent	F
Alkalinity (Carbonate [CO ₃ ²⁻] and Bicarbonate [HCO ₃ ⁻])	Titrimetric, Hach Method 8221 or equivalent	F
Conductivity	EPA Method 120.1 ^{b/}	L
Nitrate + Nitrite	EPA Method 353.1	L
Chlorides	Waters Capillary Electrophoresis Method N-601	L
Sulfate	Waters Capillary Electrophoresis Method N-601	L
Methane	RSKSOP-147/175 ^{c/}	L
BTEX, TMBs, Naphthalene, and Total Fuel Carbon	RSKSOP-133	L
CAHs and Chlorobenzenes	RSKSOP-148	L
TOC, TC, TIC	RSKSOP-102 and RSKSOP-120	L
Phenols and aliphatic/aromatic acids	RSKSOP-177	

^{a/} BTEX = benzene, toluene, ethylbenzene, and xylenes, TMBs = Trimethylbenzenes,
CAHs = Chlorinated aliphatic hydrocarbons, TOC = Total Organic Carbon,
TC = Total Carbon, TIC = Total Inorganic Carbon.

^{b/} EPA = US Environmental Protection Agency.

^{c/} RSKSOP = Robert S. Kerr Laboratory (now known as NRMRL) standard operating procedure.

TABLE 1B
SUMMARY OF GROUNDWATER ANALYTICAL METHODS
SEPTEMBER 1998
UPPER NAKNEK SITE (SS-12)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Analyte ^{a/}	Method	Field (F) or Fixed-Base Laboratory (L)
Oxidation\Reduction Potential	Direct Reading Meter	F
Dissolved Oxygen	Direct Reading Meter	F
Conductivity	Direct Reading Meter	F
Temperature	Direct Reading Meter	F
pH	Direct Reading Meter	F
Ferrous Iron (Fe ²⁺)	Colorimetric, Hach Method 8146 or equivalent	F
Hydrogen Sulfide	Colorimetric, Hach Method 8131 or equivalent	F
Sulfate	Colorimetric, Hach Method 8051 or equivalent	F
Carbon Dioxide	Titrimetric, Hach Method 1436-01 or equivalent	F
Alkalinity (Carbonate [CO ₃ ²⁻] and Bicarbonate [HCO ₃ ⁻])	Titrimetric, Hach Method 8221 or equivalent	F
Nitrate + Nitrite	Lachat FIA Method 10-107-04-2-A	L
Ammonia	Lachat FIA Method 10-107-06-1-A	L
Chlorides	Waters Capillary Electrophoresis Method N-601	L
Sulfate	Waters Capillary Electrophoresis Method N-601	L
Methane, Ethane, Ethene	RSKSOP-175 ^{b/} and RSKSOP-194	L
BTEX, TMBs, MTBE, Naphthalene, and Total Fuel Carbon	RSKSOP-133	L
CAHs and Chlorobenzenes	RSKSOP-148	L
TOC	RSKSOP-102	L

^{a/} BTEX = benzene, toluene, ethylbenzene, and xylenes, TMBs = Trimethylbenzenes,
MTBE = methyl tert-butyl ether, CAHs = Chlorinated aliphatic hydrocarbons, TOC = Total Organic Carbon.

^{b/} RSKSOP = Robert S. Kerr Laboratory (now known as NRMRL) standard operating procedure.

TABLE 2
WATER LEVEL ELEVATION DATA
UPPER NAKNEK SITE (SS-12)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Well Designation	Sampling Date	Datum Elevation (ft amsl) ^{a/}	Ground Elevation (ft amsl)	Screen Interval Top (ft bgs) ^{b/}	Screen Interval Bottom (ft bgs)	Total Depth to Water (ft bgs)	Total Depth to Water (ft btoc) ^{c/}	Elevation of Water Table (ft amsl)
ESMW-8A	9/94	32.29	29.15	5.3	10.3	6.10	9.24	23.05
	7/95	32.29	29.15	5.3	10.3	6.78	9.92	22.37
	9/98	32.29	29.15	5.3	10.3	9.2	12.3	20.0
ESMW-8B	9/94	32.18	29.15	12.9	17.9	6.30	9.33	22.85
	7/95	32.18	29.15	12.9	17.9	6.77	9.80	22.38
	9/98	32.18	29.15	12.9	17.9	7.7	10.7	21.5
ESMW-9A	9/94	25.50	21.61	0.0	4.5	0.04	3.93	21.57
ESMW-10A	9/94	23.30	21.60	1.0	6.0	0.35	2.05	21.25
	7/95	23.30	21.60	1.0	6.0	2.24	3.94	19.36
ESMW-10B	9/94	24.18	21.60	11.0	14.0	0.35	2.93	21.25
	7/95	24.18	21.60	11.0	14.0	1.05	3.63	20.55
ESMW-11A	9/94	23.53	20.52	0.0	3.0	0.21	3.21	20.32
ESMW-12A	9/94	23.46	NA ^{d/}	0.0	4.5	NA	3.61	19.85
	7/95	23.46	NA	0.0	4.5	NA	NA	NA ^{e/}
ESMW-13A	9/94	24.02	21.29	5.0	10.0	2.85	5.58	18.44
	7/95	24.02	21.29	5.0	10.0	2.52	5.25	18.77
ESMW-14A	9/94	25.04	22.17	5.0	10.0	3.65	6.52	18.52
	7/95	25.04	22.17	5.0	10.0	4.84	7.71	17.33
ESMW-15A	9/94	39.10	36.30	9.0	14.0	11.62	14.42	24.68
	7/95	39.10	36.30	9.0	14.0	12.20	15.00	24.10
	9/98	39.10	36.30	9.0	14.0	13.3	16.1	23.0
ESMW-15B	9/94	39.85	36.30	16.0	21.0	10.76	14.31	25.54
	7/95	39.85	36.30	16.0	21.0	11.35	14.90	24.95
	9/98	39.85	36.30	16.0	21.0	12.5	16.1	23.8
500	9/94	39.91	36.90	10.0	20.0	13.95	16.96	22.95
	7/95	39.91	36.90	10.0	20.0	10.29	13.30	26.61
	9/98	39.91	36.90	10.0	20.0	16.1	19.1	20.8

TABLE 2 (Continued)
WATER LEVEL ELEVATION DATA
UPPER NAKNEK SITE (SS-12)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Well Designation	Sampling Date	Datum Elevation (ft amsl) ^{a/}	Ground Elevation (ft amsl)	Screen Top (ft bgs) ^{b/}	Interval Bottom (ft bgs)	Total Depth to Water (ft bgs)	Total Depth to Water (ft btoc) ^{c/}	Elevation of Water Table (ft amsl)
501	9/94	NA	33.30	5.0	15.0	NA	12.62	NA
	7/95	NA	33.30	5.0	15.0	NA	17.72	NA
	9/98	NA	33.30	5.0	15.0	NA	14.2	NA
502	9/94	NA	20.30	1.0	11.0	NA	NA	NA
506 ^{d/}	9/94	20.49	18.51	23.0	33.0	0.91	2.89	17.60
	7/95	20.49	18.51	23.0	33.0	1.32	3.30	17.19
507	9/94	19.22	16.89	2.0	12.0	2.05	4.38	14.84
508	9/94	22.27	18.95	2.0	12.0	2.98	6.31	15.96
509	9/94	24.29	21.52	3.0	13.0	4.35	7.12	17.17
510	9/94	NA	23.30	3.0	13.0	NA	NA	NA
MW-50	9/94	35.63	34.05	4.3	14.3	8.19	9.77	25.86
	7/95	35.63	34.05	4.3	14.3	8.96	10.54	25.09
MW-51	9/94	33.74	32.57	6.7	16.7	8.63	9.80	23.94
	7/95	33.74	32.57	6.7	16.7	9.21	10.38	23.36
	9/98	33.74	32.57	6.7	16.7	NA	11.5	22.2
MW-52	9/94	25.74	24.39	0.25	9.8	3.34	4.69	21.05
	7/95	25.74	24.39	0.25	9.8	2.97	4.32	21.42
MW-53	9/94	45.15	43.81	9.9	19.9	13.53	14.87	30.28
MW-54	9/94	43.78	42.16	8.3	18.3	12.25	13.87	29.91
MW-55	9/94	44.55	43.06	10.9	20.9	13.25	14.74	29.81
MW-56	9/94	NA	17.00	1.5	6.5	NA	NA	NA
MW-57	9/94	NA	17.86	0.0	10.0	NA	NA	NA
MW-58	9/94	20.01	18.88	0.4	10.4	3.08	4.21	15.80
MW-59	9/94	NA	19.00	1.2	11.2	NA	NA	NA
MW-60	9/94	25.41	24.42	1.6	11.6	6.41	7.40	18.01
MW-61	9/94	19.33	19.33	2.4	7.4	NA	NA	NA
MW-62	9/94	NA	20.00	0.5	4.5	NA	NA	NA

TABLE 2 (Concluded)
WATER LEVEL ELEVATION DATA
UPPER NAKNEK SITE (SS-12)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Well Designation	Sampling Date	Datum Elevation (ft amsl) ^{a/}	Ground Elevation (ft amsl)	Screen Interval		Total Depth to Water (ft bgs)	Total Depth to Water (ft btoc) ^{c/}	Elevation of Water Table (ft amsl)
				Top (ft bgs) ^{b/}	Bottom (ft bgs)			
MW-88	9/94	35.98	34.01	8.0	28.0	10.41	12.38	23.60
	7/95	35.98	34.01	8.0	28.0	10.98	12.95	23.03
	9/98	35.98	34.01	8.0	28.0	12.4	14.4	21.6
MW-89	9/94	38.16	37.26	8.0	28.0	8.54	9.44	28.72
	7/95	38.16	37.26	8.0	28.0	9.68	10.58	27.58
MW-90	9/94	46.44	44.46	9.0	29.0	14.22	16.20	30.24
	7/95	46.44	44.46	9.0	29.0	15.35	17.33	29.11
MW-91	9/94	40.68	38.08	4.0	24.0	NA	NA	NA
WP-1	9/94	23.76	19.80	NA	NA	-0.59	3.37	20.39
WP-2	9/94	24.33	20.38	NA	NA	-0.03	3.92	20.41
WP-3	9/94	24.70	20.77	NA	NA	0.16	4.09	20.61

^{a/} ft amsl = feet above mean sea level.

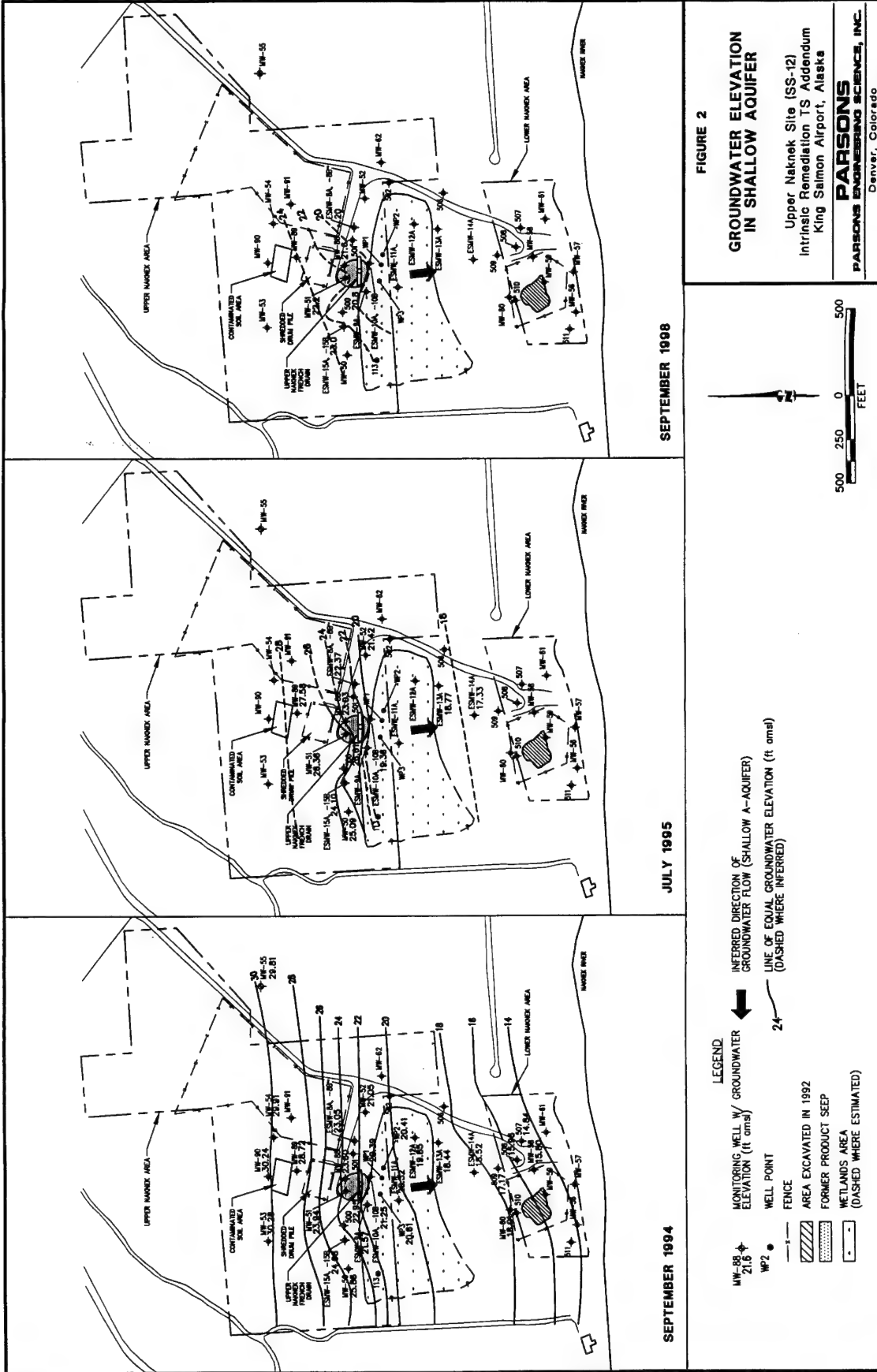
^{b/} ft bgs = feet below ground surface.

^{c/} ft btoc = feet below top of casing.

^{d/} NA=Not Available.

^{e/} 506 is screened in the B-aquifer; groundwater elevation data not used to generate contours for the shallow aquifer.

* Groundwater in ESMW-12A was observed at ground level during September 1998.



elevations measured in September 1994. In September 1998, groundwater elevations decreased from 1.7 ft (ESMW-15A and MW-51) to 3.1 ft (ESMW-8A) relative to elevations measured in September 1994.

Changes in groundwater elevation measured in the lower B-Aquifer were similar to changes measured in the upper aquifer. In July 1995, groundwater elevations in wells ESMW-8B, -10B and -15B were about 0.6 ft lower than those reported in September 1994. In September 1998, groundwater elevations in wells ESMW-8B and -15B were an average of 1.5 ft lower than elevations measured in September 1994. Changes in groundwater elevation may be attributed to seasonal variations in precipitation and recharge.

From September 1994 to September 1998, the horizontal hydraulic gradient at the site ranged from approximately 0.01 foot per foot (ft/ft) (near the wetland area) to 0.05 ft/ft (near the area of the former product seep). In July 1995, the horizontal hydraulic gradient across the wetland area was approximately 0.008 ft/ft; in September 1998, the gradient in this area was about 0.04 ft/ft.

Vertical hydraulic gradients were calculated using well pairs ESMW-8A/8B, -10A/10B, and -15A/15B. Table 3 summarizes the results of vertical gradient calculations. Vertical gradients were consistently in the downward direction for ESMW-15A/15B from September 1994 to September 1998. The direction of the vertical hydraulic gradient changed from downward to upward in well pair ESMW-8A/8B from September 1994 to July 1995 and September 1998. The vertical gradient in well pair ESMW-10A/10B, which is located on the northern boundary of the wetland, changed from no gradient in September 1994 to an upward gradient of 0.14 ft/ft in September 1998.

TABLE 3
VERTICAL HYDRAULIC GRADIENTS
UPPER NAKNEK SITE (SS-12)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Well ID	Vertical Hydraulic Gradient (ft/ft)					
	September 1994		July 1995		September 1998	
ESMW-8A/8B	-0.036	↓ ^{a/}	0.002	↑	0.37	↑
ESMW-10A/10B	0.0	-	NA ^{b/}	NA	0.14	↑
ESMW-15A/15B	-0.14	↓	-0.14	↓	-0.17	↓

^{a/} Arrow indicates direction of hydraulic gradient.

^{b/} NA = Not available.

An average hydraulic conductivity of 36 feet per day (ft/day), a median gradient of 0.013 ft/ft, and an effective porosity of 0.25 were used to calculate an average groundwater advective velocity of 680 feet per year (ft/yr) in the 1995 TS. Given the range of horizontal hydraulic gradients of 0.008 ft/ft to 0.05 ft/ft measured between September 1994 and September 1998, the average advective groundwater velocity at the

site varied from between 420 ft/yr near the wetland, to 2,600 ft/yr near the former product seep/french drain.

2.2 Dissolved BTEX in Groundwater

BTEX compounds were detected in groundwater samples from wells screened in both the upper (A-Aquifer) and lower (B-Aquifer) aquifers at Site SS-12 in July 1995 and September 1998. Twenty wells were sampled in July 1995, and 7 were re-sampled in September 1998. Table 4 lists the analytical results for petroleum hydrocarbon compounds and MTBE for each of the sampling events conducted at the site from 1989 to 1998.

Figure 3 is an isopleth map showing dissolved total BTEX concentrations in shallow groundwater at Site SS-12 in September 1994, July 1995, and September 1998. Where paired wells are present, isopleths are drawn based on the maximum concentration detected at each location. The isopleths suggest two primary BTEX source areas at the site; the first is located near the fenced fuel area, and the second is located at the former USTs near the shredded drum pile. These two source areas feed one mingled dissolved BTEX plume that appears to be approximately 1,000 feet in length and 700 feet in width, based on the inferred location of the 1 µg/L concentration isopleth for September 1994.

The highest concentrations of total BTEX have been detected at well ESMW-8A. ESMW-8A is located approximately 200 feet east of the french drain. In 1994, total BTEX was measured at well ESMW-8A at a concentration of 5,260 µg/L. By July 1995, the concentration of total BTEX at this sampling location had increased to 8,740 µg/L. In September 1998, the total BTEX concentration measured at well ESMW-8A had decreased to 7,120 µg/L. These changes in maximum BTEX concentration translate to a 40 percent increase from September 1994 to July 1995, followed by a decrease of about 19 percent from July 1995 to September 1998.

Results from the July 1995 sampling event indicate that the BTEX plume has expanded slightly. Results from the September 1998 sampling event were not adequate to fully define the extent of the BTEX plume. From July 1995 to September 1998, total BTEX concentrations in the western portions of the plume have generally increased (i.e., note increases at wells ESMW-15A, MW-51, MW-88, and 500). This suggests that the BTEX plume may have continued to expand from July 1995 to September 1998. Temporal changes in total BTEX concentrations were plotted for several wells on Figure 4. A similar pattern is suggested for the eastern portion of the plume. Specifically, concentrations of total BTEX have increased in MW-52 from 20.2 µg/L in August 1989 to 86.3 µg/L in September 1994, to 333 µg/L in July 1995. The leading edge of the 1995 BTEX plume also appears to have migrated an additional 150 to 200 feet downgradient from its September 1994 position. However, a detailed evaluation of the migration of the downgradient plume extent is not possible due to the limited analytical data available.

TABLE 4
PETROLEUM HYDROCARBON COMPOUNDS AND MTBE^d DETECTED IN GROUNDWATER
 UPPER NAKNEK SITE (SS-12)
 INTRINSIC REMEDIATION TS ADDENDUM
 KING SALMON AIRPORT, ALASKA

Sample Location	Sample Date	Fuel Carbon ^b (µg/L) ^e	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)	Total		1,3,5-TMB ^d (µg/L)	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	Naphthalene (µg/L)	MTBE (µg/L)
									Xylenes (µg/L)	BTEX ^d (µg/L)					
ESMW-8A	Sep-94	7,710	274	2,970	375	291	690	661	1,640	5,260	124	352	334	NA ^d	NA
	Jul-95	13,300	319	5,620	592	368	962	876	2,210	8,740	161	470	398	225	NA
	Sep-98	9,390	169	4,900	405	280	754	611	1,650	7,120	113	332	251	184	11.0
ESMW-8B	Sep-94	36.1	ND ^d	1.41	<1 ^f	ND	<1	1.27	1	2.68	<1	ND	3.05	NA	NA
	Jul-95	94.7	ND	<1	<1	ND	<1	<1	<1	<1	ND	ND	<1	ND	NA
	Sep-98	31.0	ND	3.10	<1	<1	1.20	1.20	2	5.50	1.10	1.20	1.40	<1	ND
ESMW-9A	Sep-94	4.92	5.9	ND	10.7	7.80	7.57	5.08	20.5	37.1	1.16	1.03	ND	NA	NA
ESMW-10A	Sep-94	496	14.0	0.97	20.7	32.6	34.7	33.3	101	136	16.1	39.1	36.5	NA	NA
	Jul-95	518	6.6	1.2	16.1	30.7	ND	24.3	55.0	78.9	11.6	29.8	24.9	29.6	NA
	Sep-94	15.2	ND	ND	ND	<1	<1	<1	<1	<1	1.06	1.53	1.83	NA	NA
ESMW-10B	Sep-94	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<10	NA
	Jul-95	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
	Sep-94	1.1	ND	1.3	ND	ND	ND	ND	ND	1.30	ND	ND	ND	ND	NA
ESMW-11A	Sep-94	7.70	4.96	<1	ND	<1	ND	ND	<1	4.96	ND	ND	ND	NA	NA
	Jul-95	63.2	3.3	3.8	<1	<1	ND	<1	<1	7.10	ND	ND	<10	<10	NA
	Sep-94	12.2	3.12	ND	1.34	1.59	<1	ND	2	6.05	ND	ND	ND	NA	NA
ESMW-13A	Sep-94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Jul-95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
	Sep-94	92.7	ND	ND	2.50	2.96	ND	ND	2.96	5.46	ND	ND	1.18	NA	NA
ESMW-14A	Sep-94	1670	<1	1.6	27.0	51.4	ND	1.10	52.5	81	79.5	ND	27.9	73.8	NA
	Jul-95	609	<1	1.5	44.4	57.6	ND	1.50	59.1	105	13.5	ND	13.9	82.2	3.8
	Sep-98	499	<1	5.57	17.2	32.9	6.50	2.10	41.5	64	25.6	1.25	15.7	NA	NA
ESMW-15B	Sep-94	552	ND	ND	4.80	11.0	ND	ND	11.0	15.8	6.90	ND	12.9	30.6	NA
	Jul-95	263	<1	<1	8.50	9.40	<1	2.10	12	20	1.90	ND	13.4	17.1	ND
	Sep-98	NA	6.23	NA	NA	NA	NA	NA	NA	6.23	NA	NA	NA	NA	NA
MW-50	Sep-94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Jul-95	0.90	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<10	NA
	Aug-89	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-51	Sep-94	1,560	3.43	205	108	131	274	147	552	868	73.8	101	62.4	NA	NA
	Jul-95	1,060	4.70	88.6	49.6	54.7	61.1	40.0	156	299	36.5	33.7	27.3	60.5	NA
	Sep-98	1,610	2.50	72.1	112	139	116	18.2	273	460	90.8	76.7	29.5	135	154
MW-52	Aug-89	NA	20.2	NA	NA	NA	NA	NA	NA	20.2	NA	NA	NA	NA	NA
	Sep-94	250	23.1	9.43	28.3	20.0	3.74	1.70	25.4	86.3	3.41	ND	3.62	NA	NA
	Jul-95	1,050	62.6	116	58.8	32.8	38.3	24.4	95.5	333	7.50	1.60	9.50	<10	NA

TABLE 4 (Continued)
 PETROLEUM HYDROCARBON COMPOUNDS AND MTBE^d DETECTED IN GROUNDWATER
 UPPER NAKNEK SITE (SS-12)
 INTRINSIC REMEDIATION TS ADDENDUM
 KING SALMON AIRPORT, ALASKA

Sample Location	Sample Date	Fuel Carbon ^b (µg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)	Xylenes (µg/L)	Total BTEX ^d (µg/L)	1,3,5-TMB ^d (µg/L)	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	Naphthalene (µg/L)	MTBE (µg/L)
MW-53	Jul-89	NA	0.01	NA	NA	NA	NA	NA	NA	0.01	NA	NA	NA	NA	NA
	Sep-94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
MW-54	Aug-89	NA	0.40	NA	NA	NA	NA	NA	NA	0.40	NA	NA	NA	NA	NA
MW-55	Aug-89	NA	ND	NA	NA	NA	NA	NA	NA	ND	NA	NA	NA	NA	NA
MW-56	Aug-89	NA	0.07	NA	NA	NA	NA	NA	NA	0.07	NA	NA	NA	NA	NA
MW-57	Aug-89	NA	3.40	NA	NA	NA	NA	NA	NA	3.40	NA	NA	NA	NA	NA
MW-58	Aug-89	NA	2.14	NA	NA	NA	NA	NA	NA	2.14	NA	NA	NA	NA	NA
MW-60	Sep-94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
MW-61	Aug-89	NA	0.89	NA	NA	NA	NA	NA	NA	0.89	NA	NA	NA	NA	NA
MW-88	Sep-92	NA	0.65	NA	NA	NA	NA	NA	NA	0.65	NA	NA	NA	NA	NA
	Sep-94	243	ND	ND	<1	2.62	<1	ND	2.62	2.62	6.17	3.62	14.5	NA	NA
	Jul-95	433	ND	ND	<1	1.50	ND	ND	1.50	1.50	4.70	1.50	11.5	<10	NA
	Sep-98	221	ND	<1	1.90	4.10	2.10	3.30	9.50	11.4	6.00	6.60	11.0	<1	1.6
MW-89	Sep-92	NA	2.37	NA	NA	NA	NA	NA	NA	2.37	NA	NA	NA	NA	NA
	Sep-94	<1	ND	ND	<1	ND	ND	ND	ND	<1	ND	ND	ND	NA	NA
	Jul-95	388	<1	ND	1.80	2.50	2.90	2.40	7.80	10	8.20	12.0	14.6	<10	NA
MW-90	Sep-92	NA	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Sep-94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Jul-95	11.8	ND	1.4	<1	ND	<1	<1	<1	1.4	ND	ND	ND	ND	NA
MW-91	Sep-92	NA	0.06	NA	NA	NA	NA	NA	NA	0.06	NA	NA	NA	NA	NA
	Sep-94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Sep-94	6.66	<1	<1	ND	<1	<1	<1	<1	<1	1.18	1.20	1.32	NA	NA
	Jul-95	416	12.8	1.2	17.4	21.9	6.40	7.40	35.7	67.1	4.20	7.90	6.50	18.8	NA
WP-2	Sep-94	5.87	1.04	1.82	ND	0.96	ND	ND	0.96	3.82	ND	ND	ND	NA	NA
	Jul-95	273	3.20	<1	ND	<1	ND	<1	<1	3.20	ND	ND	ND	ND	NA
WP-3	Sep-94	24.7	1.69	25.9	ND	ND	ND	ND	ND	27.6	ND	ND	ND	NA	NA
	Jul-95	50.9	1.60	21.3	ND	ND	ND	ND	ND	22.9	ND	ND	ND	ND	NA
500	Oct-93	NA	2.70	3.10	36.0	NA	NA	NA	NA	41.8	100	9.00	ND	NA	NA
	Sep-94	2,180	4.36	8.07	64.6	105	127	107	339	416	109	218	160	NA	NA
	Jul-95	2,420	<1	3.7	47.5	77.8	22.8	20.3	121	172	77.60	53.5	66.4	49.8	NA
	Sep-98	1,810	1.30	4.3	44.7	79.7	62.8	54.2	197	247	101	156	124	63.5	2.4

TABLE 4 (Concluded)
PETROLEUM HYDROCARBON COMPOUNDS AND MTBE^a DETECTED IN GROUNDWATER
 UPPER NAKNEK SITE (SS-12)
 INTRINSIC REMEDIATION TS ADDENDUM
 KING SALMON AIRPORT, ALASKA

Sample Location	Sample Date	Fuel Carbon ^b (µg/L) ^c	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p-Xylene (µg/L)	m-Xylene (µg/L)	o-Xylene (µg/L)	Total		1,3,5-TMB ^d (µg/L)	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	Naphthalene (µg/L)	MTBE (µg/L)
									Xylenes (µg/L)	BTEX ^e (µg/L)					
501	Oct-93	NA	1.60	3.50	28.0	NA	NA	NA	180	213	100	ND	ND	NA	NA
	Sep-94	<1	ND	ND	ND	ND	<1	ND	<1	<1	ND	ND	ND	NA	NA
	Jul-95	<1	ND	<1	<1	ND	ND	ND	ND	<1	ND	ND	ND	ND	NA
502	Oct-93	NA	210	11.0	370	NA	NA	NA	2,300	2,891	28.0	20.0	ND	NA	NA
	Nov-93	NA	ND	3.00	ND	NA	NA	NA	ND	3.00	ND	ND	ND	NA	NA
	Sep-94	77.7	ND	6.60	ND	ND	ND	ND	ND	6.60	ND	ND	ND	NA	NA
507	Jul-95	5.5	ND	3.10	ND	ND	ND	ND	ND	3.10	ND	ND	ND	NA	NA
	Oct-93	NA	ND	ND	ND	NA	NA	NA	2.00	2.00	ND	ND	ND	NA	NA
	Sep-94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
508	Oct-93	NA	ND	0.60	ND	NA	NA	NA	NA	0.60	ND	ND	ND	NA	NA
	Sep-94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Oct-93	NA	ND	ND	ND	NA	NA	NA	NA	ND	ND	ND	ND	NA	NA
510	Sep-94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA
	Oct-93	NA	ND	ND	ND	NA	NA	NA	NA	ND	ND	ND	ND	NA	NA

^a MTBE = methyl tert-butyl ether.

^b Fuel Carbon = JP-4 concentration x 0.85.

^c BTEX = benzene, toluene, ethylbenzene and xylenes; TMB = trimethylbenzene.

^d µg/L = micrograms per liter.

^e NA = Not Analyzed.

^f ND = Not Detected.

^g Analyte detected below the limit of quantitation.

Note: BTEX, TMB, and Fuel Carbon analyses performed in 1994, 1995, and 1998 using RSKSOP-133.

BTEX analyses performed in 1989, 1992, and 1993 using EPA Method SW8260.

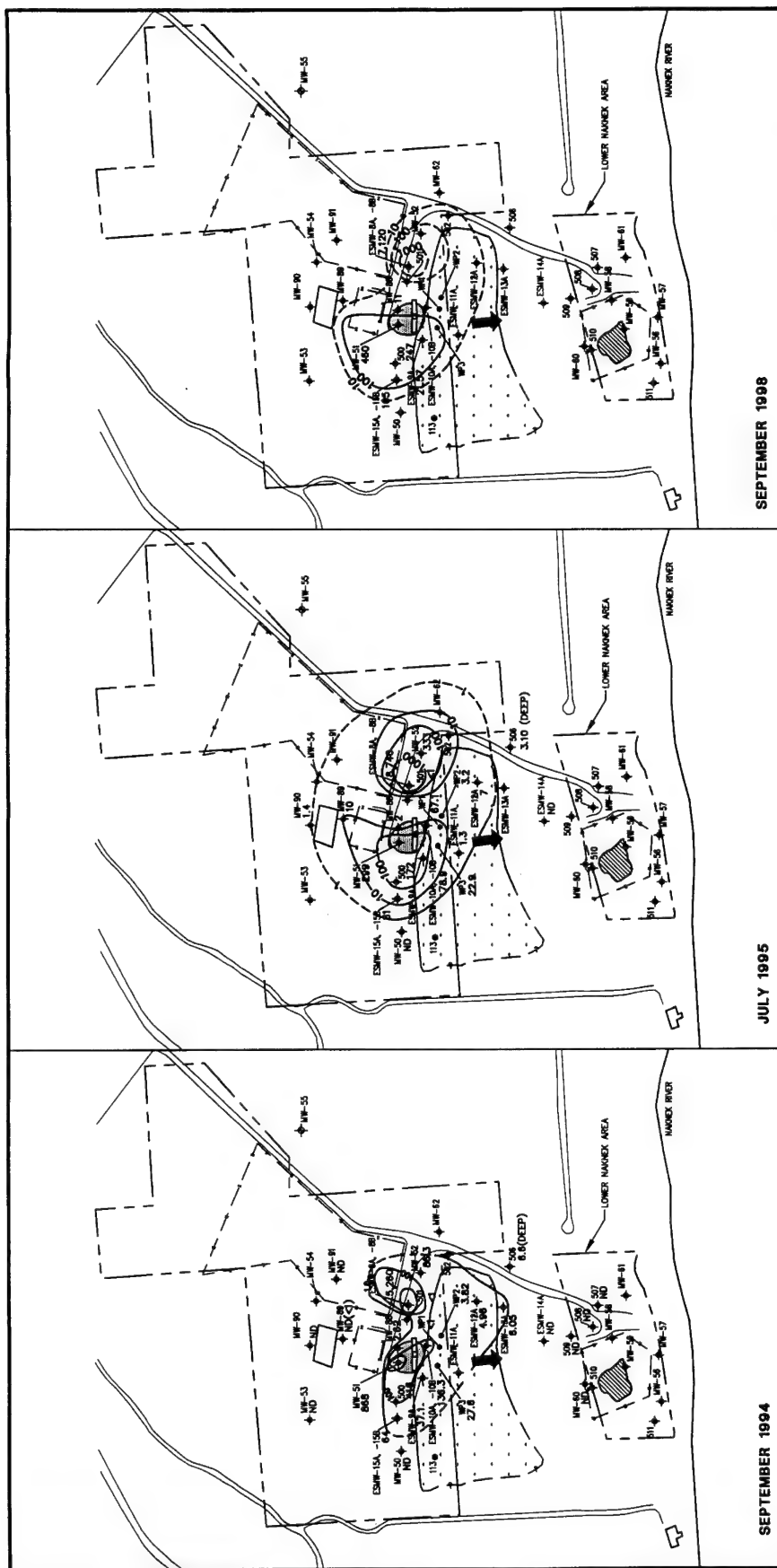
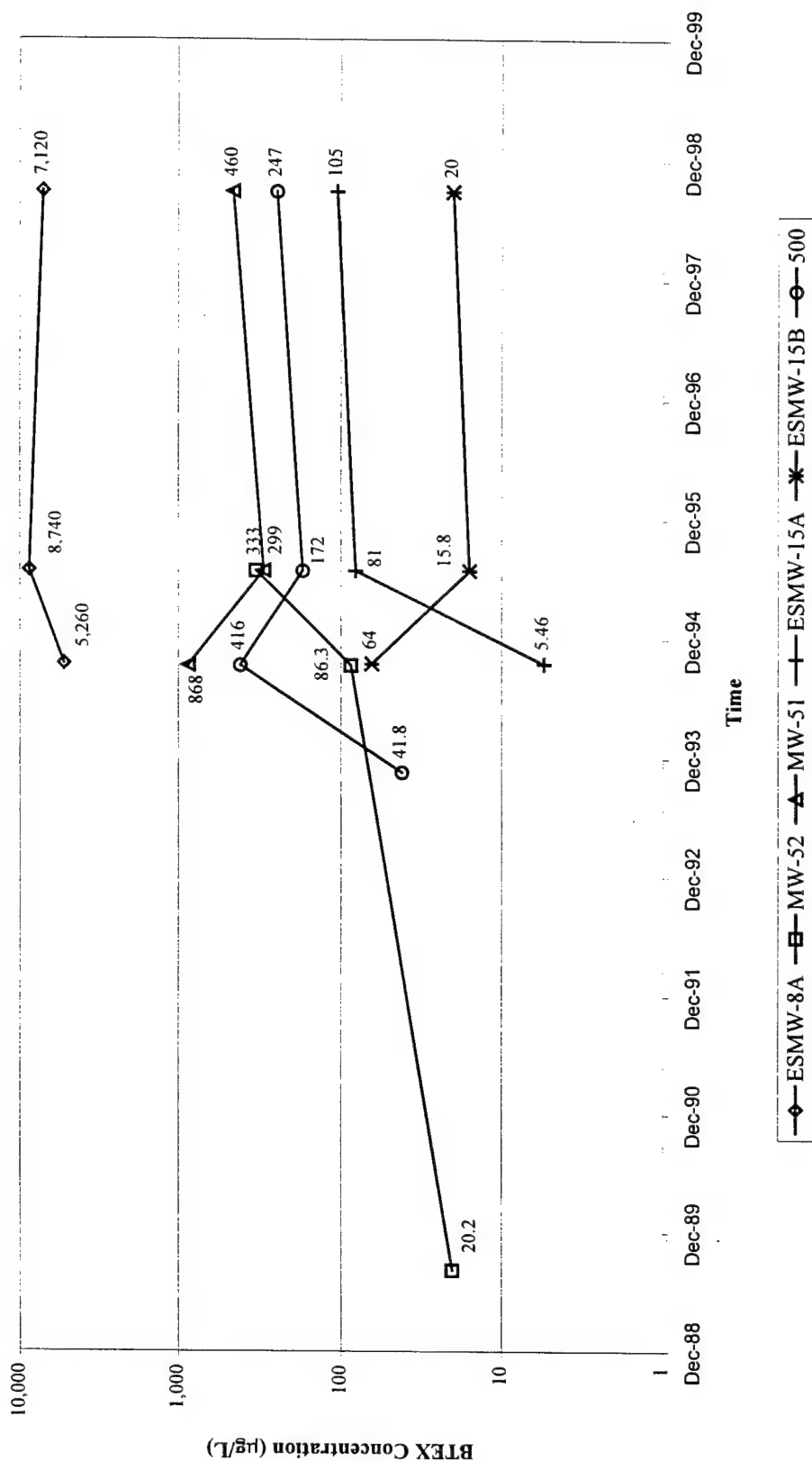


FIGURE 3
DISSOLVED BTEX IN
SHALLOW GROUNDWATER

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Denver, Colorado

-17-

FIGURE 4
TOTAL BTEX VERSUS TIME
 UPPER NAKNEK SITE (SS-12)
 INTRINSIC REMEDIATION TS ADDENDUM
 KING SALMON AIRPORT, ALASKA



The federal MCL for the BTEX compounds are 5 µg/L for benzene, 1,000 µg/L for toluene, 700 µg/L for ethylbenzene, and 10,000 µg/L for total xylenes. In July 1995, benzene was measured above its federal MCL of 5 µg/L at wells ESMW-8A, ESMW-10A, MW-52, and WP-1. In September 1998, benzene was measured at only well ESMW-8A at concentrations above its MCL; however, wells ESMW-10A, MW-52, and WP-1 were not sampled during the 1998 sampling event. The federal MCL for toluene was also exceeded at ESMW-8A. Concentrations of toluene at this sampling location were 5,620 µg/L and 4,900 µg/L in July 1995 and September 1998, respectively. No BTEX compounds were detected above their respective federal MCLs in wells screened in the lower B-Aquifer (e.g., well 506) during either of the sampling events.

The observed plume behavior is similar to that predicted by the Bioplume II model results presented in the 1995 TS (Parsons ES, 1995). Model simulation Nakneka assumed no source removal activities at the site and relied entirely on natural attenuation mechanisms to degrade the BTEX plume. The Nakneka simulation indicated that BTEX concentrations would increase as high as 7,800 µg/L, and that the plume would migrate approximately 150 feet further downgradient of the front indicated by the September 1994 sampling results. A conservative interpretation of the July 1995 sampling data suggests that the leading edge of the plume has already migrated an additional 150 to 200 feet downgradient from the 1994 position. It is not possible to infer the location of the leading edge of the dissolved BTEX plume from the limited groundwater data collected in September 1998. However, concentrations in the source areas of the dissolved BTEX plume at Site SS-12 in September 1998 were similar to the concentrations predicted by the Nakneka model.

2.3 MTBE in Groundwater

Groundwater samples collected during the September 1998 sampling event were analyzed for MTBE. MTBE is a fuel oxygenate added to gasoline to increase the octane rating and to reduce emissions. Although no historical site data exist for MTBE, the highest concentrations of MTBE were detected at sampling locations characterized by elevated BTEX concentrations. For example, in the western portion of the dissolved total BTEX plume, the highest MTBE concentration (154 µg/L) was detected at well MW-51, which also had a total BTEX concentration of 460 µg/L. In the eastern portion of the dissolved total BTEX plume, MTBE was detected at well ESMW-8A at a concentration of 11 µg/L. The maximum total BTEX concentration of 7,120 µg/L was reported for this sampling location during the 1998 sampling event.

Although MTBE is primarily a gasoline additive, it may be introduced into fuels such as JP-4 jet fuel, diesel, and heating oil in fuel distribution systems (e.g., barges and pipelines). Since the primary fuel stored at Site SS-12 was JP-4 jet fuel, MTBE may have been released into the environment as a component of the once-stored source fuel. MTBE typically migrates at a faster rate than fuel hydrocarbons in groundwater due to a relatively lower affinity for soil sorption (retardation). However, when present, MTBE is not always the compound detected at the leading edge of the dissolved plume. It is likely that source petroleum product without MTBE was released prior to the release of source product tainted with MTBE. This historical use may

explain why MTBE is present at higher concentrations within the BTEX plume interior, and may not be present at the periphery of the BTEX plume (as would be expected considering sorption characteristics alone).

2.4 Naphthalene in Groundwater

Naphthalene was analyzed for in monitoring wells sampled in July 1995 and September 1998. The federal MCL for naphthalene is 25 µg/L. Naphthalene was not detected above this standard in the lower B-Aquifer at the site. However, in July 1995, concentrations of naphthalene in the upper A-Aquifer ranged from not detected to 225 µg/L (ESMW-8A) (Table 4). In September 1998, naphthalene was measured in shallow groundwater wells at concentrations ranging from less than 1 µg/L (MW-88) to 184 µg/L (ESMW-8A).

2.5 Dissolved CAHs

All groundwater samples collected during the July 1995 and September 1998 LTM sampling events were analyzed for CAHs. During the July 1995 sampling event, no CAHs were detected in any of the sampled wells. In September 1998, chloroform was detected at a concentration of 1.8 µg/L and 1,1,1-trichloroethane was detected at a concentration of 2.7 µg/L in well MW-88. Neither of these detections are above the federal MCL for these compounds.

2.6 Inorganic Chemistry and Geochemical Indicators of Biodegradation

As discussed in the 1995 TS, microorganisms obtain energy for cell production and maintenance by facilitating thermodynamically advantageous redox reactions involving the transfer of electrons from electron donors to available electron acceptors. This results in the oxidation of the electron donor and the reduction of the electron acceptor. Electron donors at Site SS-12 are natural organic carbon and fuel hydrocarbon compounds. Fuel hydrocarbons are completely degraded or detoxified if they are utilized as the primary electron donor for microbial metabolism (Bouwer, 1992).

Electron acceptors are elements or compounds that occur in relatively oxidized states and include oxygen, nitrate, manganese, ferric iron hydroxides, sulfate, and CO₂. Microorganisms preferentially utilize electron acceptors while metabolizing fuel hydrocarbons (Bouwer, 1992). DO is utilized first as the prime electron acceptor. After the DO is consumed, anaerobic microorganisms use electron acceptors in the following order of preference: nitrate, manganese, ferric iron (Fe³⁺), sulfate, and CO₂. Anaerobic destruction of the BTEX compounds is associated with the accumulation of fatty acids, production of methane, solubilization of iron (ferrous iron), and reduction of nitrate and sulfate (Cozzarelli *et al.*, 1990; Wilson *et al.*, 1990).

Data presented in the 1995 TS indicated that biodegradation of fuel hydrocarbons was occurring via both aerobic processes and the anaerobic processes of ferric iron reduction and methanogenesis. Because only low concentrations of nitrate are present in background wells, the process of denitrification is not expected to contribute significantly to the attenuation of BTEX in site groundwater. Likewise, sulfate was detected in 1994 in relatively low concentrations at the site in background samples and

does not appear to be an important electron acceptor for the biodegradation of fuels in site groundwater. Geochemical parameters for site groundwater are discussed below. Table 5 summarizes the results of relevant geochemical parameters for the September 1994, July 1995, and September 1998 sampling events.

Oxidation-Reduction Potential

ORP, a measure of the relative tendency of a solution to accept or transfer electrons, was measured at wells in July 1995 and September 1998. The dominant electron acceptor being reduced by microbes during BTEX oxidation can be correlated to the ORP of the groundwater. ORP measurements for site wells are summarized in Table 5. Concentration isopleth maps of ORP measured at the site in September 1994, July 1995, and September 1998 are presented on Figure 5. The ORPs measured in July 1995 at the site ranged from -90 millivolts (mV) (MW-88) to 255 mV (ESMW-14A). In September 1998, the ORPs measured at Site SS-12 ranged from -71 mV (500) to 24 mV (MW-88).

Comparison of Figures 3 and 5 indicates that areas with low ORP coincide with areas characterized by high dissolved BTEX concentrations. Comparison of ORP values measured in September 1994 with those measured in July 1995 (Figure 5) suggests that the ORP of groundwater at the site may have decreased slightly. However, comparison of July 1995 and September 1998 ORP measurements indicates little change in ORP results across the site. In general, the ORP data suggest that dissolved BTEX at this site may be subjected to a variety of biodegradation processes, including aerobic respiration, denitrification, and iron reduction. However, ORP data alone cannot be used to reliably predict the electron acceptors that may be operating at a site, because the platinum electrode probes are not sensitive to some ORP couples.

Dissolved Oxygen

DO concentrations were measured at Site SS-12 in July 1995 and September 1998 (Table 5). Figure 6 shows DO concentration isopleths for the site in September 1994, July 1995, and September 1998. Comparison of Figures 3 and 6 shows that areas characterized by reduced DO concentrations relative to background conditions correspond well to areas characterized by elevated concentrations of BTEX.

Wells screened across deeper portions of the A-Aquifer and/or the B-Aquifer were characterized by higher DO concentrations than wells screened across the upper portions of the A-Aquifer in the same general location. This is consistent with the characterized vertical distribution of BTEX concentrations in well pairs. The correlation between depleted DO and elevated BTEX concentrations is a strong indication that aerobic biodegradation of the BTEX compounds has occurred and continues to occur at the site. The greatest aerobic activity is expected to occur at the upgradient perimeter of the source areas and along the fringes of the plume, because these are areas where BTEX-contaminated groundwater interacts with groundwater containing measurable concentrations of DO.

TABLE 5
GEOCHEMICAL DATA FOR GROUNDWATER
UPPER NAKNEK SITE (SS-12)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Sample Location	Sample Date	Temperature (°C) ^d	Dissolved Oxygen (mg/L) ^e	pH (su) ^e	Redox Potential (mV) ^g	Ammonia (mg/L)	Chloride (mg/L)	Sulfate ^h (mg/L)	Hydrogen Sulfide (mg/L)	Ferrous Iron (mg/L)	Manganese (mg/L)	Carbon Dioxide (mg/L)	Nitrate + Nitrite (mg/L)	Conductivity (µs/cm) ^f	Alkalinity (as CaCO ₃) (mg/L)	Methane (mg/L)	TOC ^h (mg/L)
ESMW-8A	Sep-94	8.0	0.3	6.5	-17	NA ^h	4.33	<0.5 ^h	NA	32.0	0.8	280	0.06	432	256	3.58	70.0
	Jul-95	5.4	0.1	6.6	-45	NA	5.67	<0.5	NA	40.0	NA	>210 ^h	<0.05	521	340	8.04	82.9
	Sep-98	7.0	0.8	5.2	-40	0.11	2.68	0.20	<0.1	30.0	NA	75	<0.1	540	280	0.64	56.0
ESMW-8B	Sep-94	6.7	0.7	7.4	27	NA	2.57	1.36	NA	<0.05	<0.1	38	0.06	182	80	0.13	4.0
	Jul-95	6.5	0.2	7.6	-90	NA	2.90	1.23	NA	0.1	NA	10	<0.05	144	75	0.41	3.9
	Sep-98	5.8	0.9	5.0	-11	0.62	2.79	1.46	<0.1	0.1	NA	15	<0.1	108	60	0.13	2.89
ESMW-10A	Sep-94	6.9	0.8	6.3	253	NA	4.57	8.54	NA	<0.05	<0.1	46	0.30	204	98	1.50	10.4
	Jul-95	4.5	0.6	6.8	-10	NA	4.19	2.79	NA	5.0	NA	55	<0.05	191	109	1.69	8.5
ESMW-10B	Sep-94	5.8	6.7	7.2	255	NA	3.61	2.45	NA	<0.05	<0.1	12	0.10	110	49	0.01	2.6
	Jul-95	3.2	6.9	7.1	75	NA	3.99	2.95	NA	<0.1	NA	15	<0.05	120	68	NA	1.3
ESMW-12A	Sep-94	8.0	0.8	6.1	180	NA	3.77	<0.5	NA	7.2	<0.1	106	NA	63	86	3.00	35.5
	Jul-95	5.3	0.2	6.8	10	NA	4.47	<0.5	NA	20.0	NA	125	<0.05	79	112	4.24	37.2
ESMW-13A	Sep-94	4.0	0.1	6.5	-15	NA	4.16	0.66	NA	20.0	<0.1	176	0.09	155	119	4.23	12.4
	Sep-94	4.5	0.7	6.5	110	NA	3.67	3.81	NA	0.2	<0.1	94	0.11	80	34	0.03	2.2
ESMW-14A	Sep-94	2.9	2.4	6.2	255	NA	2.39	3.16	NA	<0.1	NA	55	<0.05	58	27	0.02	2.3
	Jul-95	7.5	1.8	6.2	NA	NA	5.21	5.38	NA	40.0	0.5	>300	0.14	251	153	7.64	24.9
ESMW-15A	Sep-94	4.8	0.4	6.6	-15	NA	3.32	0.51	NA	25.0	NA	120	<0.05	186	143	1.37	13.6
	Jul-95	4.8	0.6	5.3	-23	0.25	4.45	0.35	<0.1	>50	NA	NA	<0.1	393	200	3.35	NA
ESMW-15B	Sep-94	7.5	0.2	7.0	30	NA	2.20	1.56	NA	0.2	0.3	42	0.11	212	136	0.01	5.6
	Jul-95	5.0	1.4	7.0	5	NA	3.96	1.98	NA	0.3	NA	20	<0.05	172	88	<0.001	2.8
	Sep-98	5.0	2.0	5.5	-3	<0.1	5.08	0.33	<0.1	1.5	NA	150	<0.1	430	220	0.01	8.24
500	Sep-94	5.8	0.2	6.4	-25	NA	4.08	1.57	NA	30.0	0.3	165	0.05	274	172	NA	17.7
	Jul-95	5.1	0.3	6.8	-75	NA	3.30	2.43	NA	10.0	NA	85	<0.05	220	136	0.40	13.0
	Sep-98	4.5	1.4	5.3	-71	0.26	3.33	1.70	<0.1	20	NA	70	<0.1	380	220	0.34	NA

TABLE 5 (Continued)

GEOCHEMICAL DATA FOR GROUNDWATER
UPPER NAKNEK SITE (SS-12)
INTRINSIC REMEDIATION TS ADDENDUM
KING SALMON AIRPORT, ALASKA

Sample Location	Sample Date	Temperature (°C) ^u	Dissolved Oxygen (mg/L) ^u	pH (su) ^u	Redox Potential (mV) ^u	Ammonia (mg/L)	Chloride (mg/L)	Sulfate ^u (mg/L)	Hydrogen Sulfide (mg/L)	Ferrous Iron (mg/L)	Manganese (mg/L)	Carbon Dioxide (mg/L)	Nitrate + Nitrite (mg/L)	Conductivity (us/cm) ^u	Alkalinity (as CaCO ₃) (mg/L)	Methane (mg/L)	TOC ^u (mg/L)
501	Sep-94	5.2	3.6	5.7	186	NA	3.74	4.18	NA	<0.05	<0.1	40	0.07	112	18	0.00	7.6
	Jul-95	4.9	8.0	6.5	225	NA	2.26	4.07	NA	<0.1	NA	5	<0.05	104	48	0.00	3.0
506	Sep-94	6.5	0.3	7.7	-260	NA	4.05	12.3	NA	<0.05	<0.1	8	NA	122	34	NA	0.7
	Jul-95	5.5	0.3	7.7	-55	NA	4.15	13.1	NA	<0.1	NA	5	<0.05	117	48	0.05	1.1
507	Sep-94	7.8	1.6	6.4	195	NA	4.37	3.56	NA	0.2	<0.1	48	0.09	64	68	0.01	1.6
508	Sep-94	6.5	4.4	6.1	215	NA	3.49	2.06	NA	0.1	<0.1	36	<0.05	45	48	NA	1.4
509	Sep-94	7.2	4.8	5.7	183	NA	NA	NA	NA	<0.05	<0.1	32	0.07	NA	12	NA	1.5
MW-50	Sep-94	7.8	10.5	6.3	214	NA	1.94	<0.5	NA	<0.05	<0.1	16	NA	48	14	NA	1.3
	Jul-95	4.3	11.3	6.5	245	NA	3.64	1.48	NA	<0.1	NA	35	0.19	90	41	<0.001	2.6
MW-51	Sep-94	7.0	0.1	6.6	-50	NA	3.28	1.09	NA	11.4	0.7	100	<0.05	368	205	0.16	12.6
	Jul-95	4.2	0.5	6.7	-50	NA	2.94	2.49	NA	10.0	NA	90	<0.05	164	116	0.12	14.2
	Sep-98	5.2	0.7	5.1	-48	<0.1	2.71	1.95	<0.1	8	NA	96	0.46	400	195	0.02	NA
MW-52	Sep-94	8.3	0.5	6.4	-35	NA	3.08	<0.5	NA	5.9	0.3	60	<0.05	187	93	NA	16.4
	Jul-95	6.5	2.7	7.1	-15	NA	2.45	1.16	NA	5.0	NA	30	<0.05	177	95	0.43	9.7
MW-53	Sep-94	7.2	10.9	6.3	195	NA	6.12	<0.5	NA	<0.05	<0.1	14	0.09	108	38	NA	1.1
MW-60	Sep-94	7.1	4.3	5.8	200	NA	3.84	<0.5	NA	<0.05	0.1	40	0.09	53	15	NA	3.1
MW-88	Sep-94	5.2	1.2	6.2	92	NA	7.57	4.88	NA	3.2	0.5	112	<0.05	200	80	NA	3.9
	Jul-95	4.4	3.5	6.7	85	NA	4.58	3.84	NA	3.0	NA	35	<0.05	113	54	<0.001	1.8
	Sep-98	6.0	2.0	5.0	24	<0.1	3.76	6.23	<0.1	5	NA	45	<0.1	276	120	ND ^v	NA
MW-89	Sep-94	6.9	0.3	6.2	143	NA	3.44	2.86	NA	0.1	<0.1	24	0.05	111	43	NA	2.3
	Jul-95	4.9	0.3	6.8	17	NA	3.63	2.69	NA	<0.1	NA	25	<0.05	94	48	<0.001	1.4
MW-90	Sep-94	5.8	11.7	6.7	144	NA	3.72	2.61	NA	<0.05	<0.1	14	0.07	90	33	NA	4.0
	Jul-95	4.0	12.6	6.9	185	NA	3.29	2.23	NA	<0.1	NA	20	<0.05	77	41	ND	1.8
MW-91	Sep-94	6.8	0.2	7.3	220	NA	2.92	3.33	NA	<0.05	0.1	8	0.13	86	35	<0.001	0.7

TABLE 5 (Concluded)
GEOCHEMICAL DATA FOR GROUNDWATER
 UPPER NAKNEK SITE (SS-12)
 INTRINSIC REMEDIATION TS ADDENDUM
 KING SALMON AIRPORT, ALASKA

Sample Location	Sample Date	Temperature (°C) ^d	Dissolved Oxygen (mg/L) ^d	pH (au) ^e	Redox Potential (mV) ^f	Ammonia (mg/L)	Chloride (mg/L)	Sulfate ^g (mg/L)	Hydrogen Sulfide (mg/L)	Ferrous Iron (mg/L)	Manganese (mg/L)	Carbon Dioxide (mg/L)	Nitrate + Nitrite (mg/L)	Conductivity (µs/cm) ^h	Alkalinity (as CaCO ₃) (mg/L)	Methane (mg/L)	TOC ⁱ (mg/L)
WP-1	Sep-94	8.7	1.0	6.4	37	NA	15.2	<0.5	NA	8.0	0.1	80	<0.05	174	96	0.77	7.9
	Jul-95	3.6	0.7	6.7	-10	NA	4.08	<0.5	NA	10.0	NA	75	<0.05	155	95	6.61	26.7
WP-2	Sep-94	9.8	2.5	6.9	-50	NA	20.7	2.01	NA	15.0	0.2	60	<0.05	245	140	1.35	12.7
	Jul-95	3.7	1.6	6.3	60	NA	NA	NA	NA	15.0	NA	175	NA	NA	102	NA	NA
WP-3	Sep-94	7.7	0.3	6.0	60	NA	16.5	1.66	NA	44.0	<0.1	200	0.13	85	69	5.61	NA
	Jul-95	7.2	1.7	6.1	40	NA	NA	NA	NA	45.0	NA	265	NA	NA	88	NA	NA

^a Sulfate data listed for September 1998 was analyzed by Waters Capillary Electrophoresis Method N-60.

^b TOC = Total organic carbon.

^c °C = degrees Celsius.

^d mg/L = Milligrams per liter.

^e su = Standard pH units.

^f mV = Millivolts.

^g µs/cm = Microseimens per centimeter.

^h NA = Not analyzed.

ⁱ < = Analyte detected below stated lower limit of quantitation.

^j > = Analyte detected above stated upper limit of quantitation.

^k ND = Not Detected

Nitrate+ Nitrite

Nitrate+nitrite concentrations were measured at Site SS-12 in September 1994, July 1995, and September 1998. Concentrations of nitrate+nitrite were generally below the analytical method reporting limit of quantitation (see Table 5). Due to the general lack of nitrate/nitrite in groundwater at the site, nitrate is not considered an important electron acceptor. This conclusion is consistent with the data presented in the 1995 TS (Parsons ES, 1995).

Ferrous Iron

Dissolved ferrous iron (Fe^{2+}) is the reduced form of iron and a byproduct of the oxidation of BTEX via ferric iron (Fe^{3+}) reduction. Ferrous iron concentrations measured at the site are presented in Table 5. Ferrous iron concentration isopleth maps for September 1994, July 1995, and September 1998 are shown on Figure 7. Comparison of Figures 3 and 7 shows that areas characterized by elevated total BTEX concentrations also are characterized by elevated concentrations of ferrous iron. Concentrations of ferrous iron measured at the site during July 1995 ranged from less than the method detection limit (0.1 milligrams per liter [mg/L]) to 45 mg/L (well WP-3). Similar concentrations of Fe^{2+} were detected in groundwater in September 1998, with notable increases at monitoring wells 500 (10 mg/L to 20 mg/L) and ESMW-15A (25 mg/L to >50 mg/L). These wells are located in the western core of the BTEX plume, where an increase in BTEX concentrations was observed in September 1998. These analytical results suggest that the area of iron reduction has expanded along with increasing BTEX concentrations.

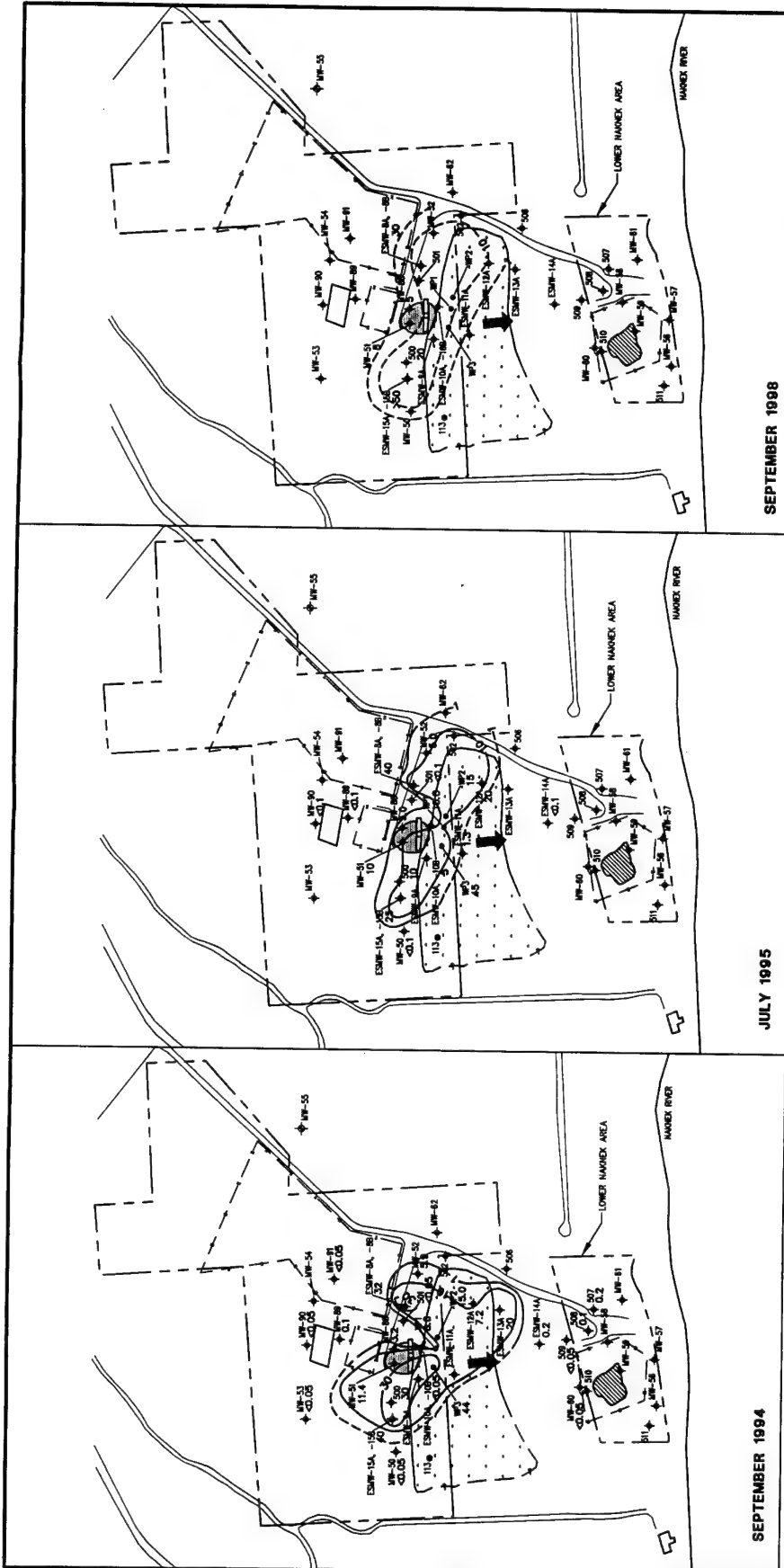
Recent evidence suggests that the reduction of ferric iron to ferrous iron cannot proceed without microbial mediation (Lovley and Phillips, 1988; Lovley *et al.*, 1991; Chapelle, 1993); therefore, the presence of ferrous iron strongly suggests that ferric iron is being used as an electron acceptor at the site. Furthermore, the coincident ferrous iron and BTEX plumes indicate that the reduction of ferric iron to ferrous iron is occurring during biodegradation of BTEX compounds

Sulfate

Sulfate concentrations were measured at groundwater monitoring wells during the September 1994, July 1995, and September 1998 sampling events. As reported in the 1995 TS, sulfate concentrations are low and did not exhibit an inverse relationship with BTEX concentrations. Consequently, 1995 and 1998 sample data supports the conclusion that sulfate still does not appear to be an important electron acceptor for the biodegradation of BTEX at the site.

Methane

The presence of methane in BTEX-contaminated groundwater indicates that anaerobic biodegradation of BTEX is occurring via the microbially mediated process of methanogenesis (carbon dioxide reduction). During methanogenesis, an anaerobic biodegradation process, CO_2 (or acetate) is used as an electron acceptor and methane is



LEGEND

- MW-88 + FERROUS IRON CONCENTRATION (mg/L)
- WF2 • WELL POINT
- FENCE
- ▨ AREA EXCAVATED IN 1992
- ▤ FORMER PRODUCT SEEP
- ▥ WETLANDS AREA (DASHED WHERE ESTIMATED)

INFERRED DIRECTION OF GROUNDWATER FLOW

10.0 — LINE OF EQUAL FERROUS IRON CONCENTRATION (mg/L) (DASHED WHERE INFERRED)

NOTE: FERROUS IRON CONCENTRATION FROM PAIRED WELL WITH HIGHER SITE CONCENTRATION IS POSTED AND CONTOURED.

SEPTEMBER 1994

JULY 1995

SEPTEMBER 1998

FIGURE 7

FERROUS IRON ISOPLETH MAPS FOR SHALLOW GROUNDWATER

Upper Naknek Site (SS-12)
Intrinsic Remediation TS Addendum
King Salmon Airport, Alaska

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

produced. Methane concentrations measured in groundwater at the site are included in Table 5.

Methane concentration isopleth maps for the 1994, 1995, and 1998 sampling events are presented on Figure 8. Comparison of Figures 3 and 8 shows that the areas with the highest total BTEX concentrations have elevated methane concentrations. The correlation of elevated methane concentrations with the highest BTEX concentrations provides strong evidence that anaerobic biodegradation of the BTEX compounds is occurring at the site through the microbially mediated process of methanogenesis. In July 1995, methane concentrations at Site SS-12 ranged from less than the limit of quantitation (0.001 mg/L) to 8.04 mg/L. From July 1995 to September 1998, the area of elevated methane concentrations appears to have decreased, although some wells with elevated methane concentrations in July 1995 were not re-sampled in September 1998 (e.g., ESMW-12A and WP-1). Methane concentrations also decreased in several wells from the 1995 to the 1998 sampling event (e.g., ESMW-8A, -8B, MW-51, and 500). Comparison of Figure 8 and Figure 6 (DO isopleth map) show that areas of elevated methane concentration correspond to anaerobic (DO less than 1 mg/L) zones of the aquifer.

Alkalinity

Alkalinity is a measure of the ability of water to buffer changes in pH caused by the addition of biologically generated acids. Biodegradation of BTEX produces carbon dioxide which, when mixed with water in the proper conditions, produces carbonic acid. In aquifers that have carbonate minerals as part of the matrix, carbonic acid dissolves these minerals, increasing the alkalinity of the groundwater. Therefore, an increase in alkalinity can be observed in areas of active intrinsic bioremediation of BTEX.

Total alkalinity [measured as calcium carbonate (CaCO_3)] of groundwater samples collected at the site in September 1994, July 1995, and September 1998 are summarized in Table 5. An increase in alkalinity relative to background concentrations suggests that additional buffering capacity was generated to address acids produced during biodegradation of BTEX. Increases in alkalinity above background concentrations can be observed at Site SS-12. Alkalinities generally are below 100 mg/L in areas with low concentrations of dissolved BTEX, while more highly contaminated areas generally have an alkalinity greater than 200 mg/L. The highest concentration of alkalinity detected at Site SS-12 was measured at ESMW-8A, which also is the sampling location characterized by the maximum total BTEX concentration.

Volatile Fatty Acids

In July 1995, wells ESMW-8A and ESMW-15B were sampled for phenols and aliphatic/aromatic acids. These compounds may be representative of intermediate degradation byproducts produced by petroleum hydrocarbon biodegradation. Laboratory results indicated high confidence in the presence of higher-molecular-weight aliphatic and aromatic acids. USEPA NRML researchers reported that ESMW-8A showed extremely high concentrations of analyzed acids, including aliphatic esters and

carboxylic acids. Concentrations of total fatty acids ranged up to 5 mg/L. These analytical results provide further evidence that fuel hydrocarbon biodegradation is continuing at this site. USEPA correspondence regarding these analyses is presented in Attachment A.

3.0 CONCLUSIONS AND RECOMMENDATIONS

Results from groundwater monitoring conducted during July 1995 and September 1998 indicate that natural attenuation of BTEX continues at Site SS-12. The distribution of electron acceptors/metabolic byproducts that are involved in biologically mediated redox reactions indicate that microbially mediated redox reactions continue to occur within the BTEX plume. Data suggest that degradation of dissolved BTEX at this site is occurring via aerobic respiration, ferric iron oxidation, and methanogenesis. The BTEX plume appears to have expanded slightly, and only limited downgradient migration of the leading edge of the dissolved BTEX plume is suggested by 1995 sampling results. However, the limited number of wells sampled in September 1998 do not provide adequate data to delineate the current downgradient extent of the BTEX plume.

The observed plume behavior is similar to that predicted by the Bioplume II model results presented in the 1995 TS (Parsons ES, 1995). Model simulation NakneKA assumed no source removal activities at the site and relied entirely on natural attenuation mechanisms to degrade the BTEX plume. The NakneKA simulation indicated that BTEX concentrations would increase as high as 7,800 µg/L, and that the plume would migrate approximately 150 feet further downgradient of the front indicated by the September 1994 sampling results. A conservative interpretation of the July 1995 sampling data suggests that the leading edge of the plume has already migrated an additional 150 to 200 feet downgradient from the 1994 position. It is not possible to infer the location of the leading edge of the dissolved BTEX plume from the limited groundwater data collected in September 1998. However, concentrations in the source areas of the dissolved BTEX plume at Site SS-12 in September 1998 were similar to the concentrations predicted by the NakneKA model.

Continued LTM is recommended to verify the effectiveness of natural attenuation processes to stabilize the BTEX plume, and to evaluate the need for engineered source reduction activities. The 1995 TS included a LTM plan based on 5 existing groundwater monitoring locations (i.e., ESMW-8A, -13A, MW-51, MW-54, and 506). Two of the key wells in this plan were not sampled in 1998 (i.e., well 506 and ESMW-13A, both of which are located at the downgradient extent of the known dissolved plume). It is recommended that future LTM sampling events include all 5 LTM wells, plus well locations near the suspected leading edge of the dissolved BTEX plume (ESMW-11A, ESMW-12A, and MW-62), indicator wells within the plume (ESMW-15A, ESMW-15B, and 500), as well as a "true" background well (MW-53), in order to adequately support an evaluation of long-term plume behavior over time at the site.

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Ref: 95/JAD46

September 14, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift *SV*

King Salmon

Dear Don:

As requested in Service Request # SF-1-135, headspace GC/MS analysis of 25 King Salmon water samples for tetrachloroethene (PCE), trichloroethene (TCE), dichloroethenes (DCE's) and vinyl chloride was completed. The samples were received on July 31 & August 2, 1995 and analyzed on August 16, 1995. RSKSOP-148 (Determination of Volatile Organic Compounds in Water by Automated Headspace Gas Chromatography/Mass Spectrometry (Saturn II Ion Trap Detector)) was used for this analysis.

An internal standard calibration method was established for the six compounds. The standard curves were prepared from 1.0 to 2000 ppb. The lower calibration limits were 1.0 ppb.

A quantitation report for the samples, lab duplicates, field duplicates, QC standards and lab blanks is presented in Table 1.

If you should have any questions, please feel free to contact me.

Sincerely,

John Allen Daniel
John Allen Daniel

xc: R.L. Cosby
G.B. Smith
D.D. Fine
J.L. Seeley *JS*

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

Concentration = ppb

[illegible]

ATTACHMENT A
ANALYTICAL RESULTS
JULY 1995

ANALYSIS PERFORMED 8-10-95

SAMPLE	METHANE
LAB BLANK	BLQ
GP-10	BLQ
EMCON-1	BLQ
EMCON-2	BLQ
WP-1	6.61
" FIELD DUP	6.89
GP-1	BLQ
GP-2	BLQ
GP-3	BLQ
GP-4	BLQ
MW51	0.115
" LAB DUP	0.108

ANALYSIS PERFORMED 8-14-95

SAMPLE	METHANE
LAB BLANK	BLQ
MW-52	0.432
MW-88	BLQ
" FIELD DUP	BLQ
MW-89	BLQ
MW-90	ND
" FIELD DUP	BLQ
MW-92	BLQ
MW-94	0.390
MW-500	0.400
MW-501	0.001
MW-506	0.052
" LAB DUP	0.048
10 PPM CH4	10.00
100 PPM CH4	99.93
1000 PPM CH4	1071.46
1% CH4	1.00
10% CH4	10.00

LIMIT OF QUANTITATION
METHANE

0.001

SAMPLE UNITS ARE mg/L.
STANDARDS UNITS CORRESPOND
TO THE SAMPLE COLUMN.

BLQ DENOTES BELOW LIMIT OF QUANTITATION
ND DENOTES NONE DETECTED.
NA DENOTES NOT ANALYZED.



Ref: 95-SH14/vg
95-TL40/vg

August 23, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

King Salmon

Dear Don:

Attached are TOC results for a set of 12 soils submitted August 14, 1995 under Service Request #SF-1-135. Sample analysis was begun August 18 and completed August 23 using RSKSOP-102 and RSKSOP-120. Blanks, duplicates, AQC samples and a Leco standard soil were analyzed along with your samples, as appropriate, for quality control.

If you have any questions concerning this data, please feel free to ask me.

Sincerely,

Sharon Hightower
Sharon Hightower

Teresa Leon
Teresa Leon

xc: R.L. Cosby
J.L. Seeley *js*
G.B. Smith

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

Sample	Soil Filtrate % OC	Solids % OC	Total Soil %TOC	Mean %TOC
FTO1 SSO1 #1				
1-1	.111	1.13	1.24	1.24
1-2	.107	1.12	1.23	
FTO1 SSO1 #2				
1-1	.159	.728	.887	.943
1-2	.168	.830	.998	
FTO1 SSO2 #1				
1-1	.058	.392	.450	.470
1-2	.063	.426	.489	
FTO1 SSO2 #2				
1-1	.055	.489	.544	.554
1-2	.061	.502	.563	
UN Site SS-3 #1				
1-1	.318	3.07	3.39	3.58
1-2	.314	3.45	3.76	
UN Site SS-3 #2				
1-1	.721	11.21	11.93	12.2
1-2	.767	11.71	12.48	
UN Site SS-4 #1				
1-1	.476	7.52	8.00	7.91
1-2	.484	7.34	7.82	
UN Site SS-4 #2				
1-1	.410	6.94	7.35	7.26
1-2	.384	6.78	7.16	
UN Site SS-05 #1				
1-1	1.17	18.0	19.2	19.8
1-2	1.24	19.2	20.4	
UN Site SS-05 #2				
1-1	1.29	18.2	19.5	19.3
1-2	1.28	17.9	19.1	
UN Site SS-06 #1				
1-1	1.33	21.1	22.4	23.1
1-2	1.33	22.4	23.7	
UN Site SS-06 #2				
1-1	1.09	22.4	23.5	23.1
1-2	1.07	21.6	22.7	
Leco standard		1.04		
WP033-II std	35.1			
Leco standard T.V.=1.00±.04				
WP033-II standard T.V.=35.0				

**MANTECH
TECHNOLOGIES**

King Salmon

Ref: 95-TL42/vg

August 24, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift *SV* *King Salmon*

Dear Don:

Attached are TC, TOC, and TIC results for a set of 48 liquid samples received by MERSC July 31, 1995 under Service Request #SF-1-135. Determinations were begun August 21, 1995 and completed August 23, 1995 using RSKSOP-102.

A known AQC sample was analyzed with your samples for quality control. If you have any questions concerning these results please feel free to contact me.

Sincerely,

Teresa Leon

Teresa Leon

xc: R.L. Cosby
J.L. Seeley *JS*
G.B. Smith

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

FT01

TC, TOC, TIC FOR DON KAMPBELL (SF-1-135)

SAMPLE	MG/L TC	MG/L TOC	MG/L TIC	SAMPLE	MG/L TC	MG/L TOC	MG/L TIC
EMCON-1	56.5	10.2	46.3	GP-2	10.9	1.5	9.4
EMCON-2	21.2	2.2	19.0	GP-2 DUP		1.5	
WP-1	32.6	26.7	5.9	GP-3	17.3	1.7	15.6
ESMW-1A	30.0	1.4	28.6	GP-4	14.9	1.8	13.1
ESMW-1B	19.5	2.2	17.3	GP-5	14.1	3.2	10.9
ESMW-2A	18.8	5.1	13.7	GP-6	20.0	1.9	18.1
ESMW-2B	17.2	3.1	14.1	GP-6 DUP	19.9		
ESMW-3A	14.3	2.4	11.9	GP-7	27.2	3.4	23.8
ESMW-4A	26.6	6.2	20.4	GP-8	12.3	1.5	10.8
ESMW-5A	24.6	3.1	21.5	GP-9	77.1	12.3	64.8
ESMW-5A DUP		3.1		GP-10	38.5	6.8	31.7
ESMW-5B	16.8	1.2	15.6	GP-10 DUP	38.6	6.8	31.8
ESMW-6B	12.9	2.0	10.9				
ESMW-8A	154.9	82.9	72.0	WPO33-II			
ESMW-8B	20.0	3.9	16.1				
ESMW-8B DUP	20.1						
ESMW-12A	29.4	37.2	<0.1				
ESMW-14	12.8	2.3	10.5				
ESMW-15A	37.4	13.6	23.8				
ESMW-15B	23.0	2.8	20.2				
ESMW-16	34.0	10.4	23.6				
MW-10A	32.5	8.5	24.0				
MW-10A DUP		8.7					
MW-10B	14.7	1.3	13.4				
MW-50	12.7	2.6	10.1				
MW-51	35.4	14.2	21.2				
MW-52	47.4	9.7	37.7				
MW-52 DUP	47.2						
MW-88	16.1	1.8	14.3				
MW-89	12.4	1.4	11.0				
MW-90	9.3	1.8	7.5				
MW-92	18.9	3.6	15.3				
MW-93	10.3	1.6	8.7				
MW-94	10.2	1.5	8.7				
MW-94 DUP		1.4					
MW-95	16.3	5.0	11.3				
MW-435	21.0	4.3	16.7				
MW-460B	23.5	5.3	18.2				
MW-462C	13.0	2.6	10.4				
MW-462C DUP	13.0						
MW-500	40.8	13.0	27.8				
MW-501	18.5	3.0	15.5				
MW-506	10.7	1.1	9.6				
KSMW-653	30.4	4.8	25.6				
KSMW-653 DUP	30.3						
GP-1	28.1	1.8	26.3				

TRUE VALUES: WPO33-II = 35.0 MG/L



Ref: 95-LP110/vg
95-TH63/vg
95-BS3/vg

August 8, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift *SV*

Dear Don:

Attached are inorganic results for two sets of samples from King Salmon AFB, Alaska submitted to MERSC July 31, 1995 as a part of Service Request #SF-1-135. The samples were analyzed July 31 through August 3 using EPA Methods 353.1, 120.1 and Waters capillary electrophoresis Method N-601.

Blanks, spikes, duplicates, and known AQC samples were analyzed along with your samples for quality control. If you have any questions concerning this data, please feel free to contact us.

Sincerely,

Lynda Pennington
Lynda Pennington

Tim Hensley
Tim Hensley

Brad Scroggins
Brad Scroggins *by LKP*

xc: R.L. Cosby
J.L. Seeley *JS*
G.B. Smith

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

<u>Sample</u>	<u>mg/L</u> <u>Cl⁻</u>	<u>mg/L</u> <u>SO₄⁼</u>	<u>mg/L</u> <u>NO₂⁻+NO₃⁻(N)</u>	<u>μS/cm</u> <u>Conductivity</u>
ESMW-1A	2.07	1.39	<.05	161
ESMW-1B	3.47	3.71	0.25	134
ESMW-2A	2.42	4.80	1.38	117
ESMW-2B	3.04	3.13	0.38	113
ESMW-3A	3.70	0.97	<.05	100
ESMW-4A	3.99	3.16	2.52	157
ESMW-5A	3.59	2.33	<.05	162
ESMW-5A Dup	3.64	2.34	----	---
ESMW-5B	3.43	2.20	<.05	146
ESMW-5B Dup	----	----	<.05	147
ESMW-6B	2.44	1.52	<.05	87
ESMW-15A	3.32	0.51	<.05	186
ESMW-15B	3.96	1.98	<.05	172
MW-50	3.64	1.48	0.19	90
MW-93	3.39	2.77	0.13	70
MW-95	3.30	1.60	<.05	116
MW-435	2.53	1.01	0.11	141
MW-435 Dup	2.50	1.06	----	---
MW-460B	2.78	5.85	0.79	161
MW-460B Dup	----	----	0.79	160
MW-462C	2.65	0.94	0.13	78
KSMW-653	3.17	2.90	0.34	181
EM CON-1	3.38	<.50	<.05	323
EM CON-1 Dup	----	----	----	323
EM CON-2	6.02	2.91	2.21	150
WP-1	4.08	<.50	<.05	155
ESMW-8A	5.67	<.50	<.05	521
ESMW-8B	2.90	1.23	<.05	144
ESMW-8B Dup	2.88	1.18	----	---
ESMW-12A	4.47	<.50	<.05	79
ESMW-14	2.39	3.16	<.05	58
ESMW-16	4.82	1.38	<.05	173
MW-10A	4.19	2.79	<.05	191
MW-10B	3.99	2.95	<.05	120
MW-10B Dup	----	----	<.05	---
MW-51	2.94	2.49	<.05	164
MW-52	2.45	1.16	<.05	177
MW-52 Dup	2.56	1.19	----	---
MW-88	4.58	3.84	<.05	113
MW-89	3.63	2.69	<.05	94
MW-90	3.29	2.23	<.05	77
MW-92	2.81	3.61	1.07	104
MW-92 Dup	----	----	----	104
MW-94	2.51	1.61	<.05	74
MW-94 Dup	----	----	<.05	---
MW-500	3.30	2.43	<.05	220
MW-501	2.26	4.07	<.05	104
MW-506	4.15	13.1	<.05	117
MW-506 Dup	4.27	13.0	----	---
GP-1	4.17	1.89	2.41	172
GP-2	2.15	<.50	1.41	75

<u>Sample</u>	<u>mg/L</u> <u>Cl⁻</u>	<u>mg/L</u> <u>SO₄⁼</u>	<u>mg/L</u> <u>NO₂⁻+NO₃⁻(N)</u>	<u>μS/cm</u> <u>Conductivity</u>
GP-3	3.19	1.67	.80	120
GP-4	3.77	1.29	1.05	107
GP-5	3.81	3.01	.89	89
GP-5 Dup	----	----	.88	---
GP-6	3.53	3.03	2.31	161
GP-7	4.27	4.00	2.09	184
GP-7 Dup	4.54	3.94	----	183
GP-8	2.31	1.77	2.02	93
GP-9	3.27	3.49	<.05	415
GP-10	3.27	3.51	1.66	204
Blank	<.5	<.5	<.05	---
Blank	<.5	<.5	<.05	---
WP033	59.0	21.2	0.27	---
WP033	58.3	20.5	.27	---
WP033 T.V.	59.2	22.0	0.27	---
Spike Rec.	100%	103%	100%	---
Spike Rec.	100%	101%	99%	---

(L/c)

MANTECH TECHNOLOGY

Ref: 95-JH52/vg

August 25, 1995

King Salmon

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift *SAV*

Dear Don:

Find attached results for methane on samples received on July 31, 1995 and analyzed on August 7, 8, 9, 10, and 14, 1995 under Service Request #SF-1-135 Mod. 1. Samples were prepared and calculations were done as per RSKSOP-175. Analyses were performed as per RSKSOP-147.

Sample # ESMW-10B was wasted due to loose septa caps on both duplicates. If you have any questions, feel free to contact me.

Sincerely,

Jeff Hickerson

Jeff Hickerson

xc: R.L. Cosby
J.L. Seeley *JS*
G.B. Smith

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

ANALYSIS PERFORMED 8-7-95

FT01

SAMPLE METHANE

LAB BLANK	BLQ
ESMW-1A	BLQ
ESMW-1B	BLQ
ESMW-2A	BLQ
ESMW-2B	BLQ
" FIELD DUP	BLQ
ESMW-3A	0.126
ESMW-4A	0.001
ESMW-5A	BLQ
ESMW-5B	0.001
ESMW-6B	0.074
" LAB DUP	0.071

ANALYSIS PERFORMED 8-8-95

SAMPLE METHANE

LAB BLANK	BLQ
ESMW	BLQ
ESMW-15A	1.37
ESMW-15B	BLQ
MW-50	BLQ
" LAB DUP	BLQ
MW-93	0.123
MW-95	BLQ
MW-435	0.001
MW-460B	BLQ
MW-462C	0.045
" FIELD DUP	0.038
KAMW-653	BLQ

ANALYSIS PERFORMED 8-9-95

SAMPLE METHANE

LAB BLANK	BLQ
ESMW-8A	8.04
ESMW-8B	0.413
ESMW-10A	1.69
ESMW-12A	4.24
" FIELD DUP	3.73
ESMW-14	0.015
ESMW-16	5.25
GP-5	BLQ
GP-6	0.025
GP-7	0.032
" LAB DUP	0.031
" FIELD DUP	0.067
GP-8	BLQ
GP-9	BLQ

<u>Sample</u>	<u>Total Alkalinity</u>	<u>Ferrous Iron</u>	<u>CO₂-</u>	<u>Redox</u>	<u>pH</u>	<u>D.O.</u>	<u>Temp °C</u>
ESMW-12A	112	20.0	125	10.0	6.80	0.2	5.3
WP-1	95.2	10.0	75.0	-10.0	6.74	0.7	3.6
WP-2	102	15.0	175	60.0	6.26	1.6	3.7
WP-3	88.4	45.0	265	40.0	6.13	1.7	7.2
MW-94	40.8	<.1	20.0	125	6.92	0.8	5.7
ESMW-11 Surface	N/A	1.0	N/A	35.0	N/A	2.5	13.6
GP-10	102	<.1	90.0	240	6.33	0.4	5.1
GP-1	81.6	<.1	75.0	225	6.36	2.2	5.3
GP-7	74.8	2.50	70.0	145	6.37	0.7	2.5
EMCON-1	177	5.0	70.0	-35.0	6.92	0.5	4.5
GP-2	40.8	<.1	25.0	95.0	6.61	9.9	4.6
GP-3	54.4	<.1	25.0	165	6.83	5.8	4.4
GP-5	40.8	<.1	30.0	155	6.45	N/A	N/A
GP-8	27.2	<.1	30.0	100	6.46	0.0	5.5
GP-8 Dup	27.2	<.1	30.0	95.0	6.48	-----	-----
GP-6	61.2	<.1	15.0	90.0	7.02	0.8	4.9
GP-9	23.1	15.0	105	-65.0	6.78	0.5	5.9
GP-4	40.8	<.1	30.0	200	6.72	10.4	6.1
EMCON-2	54.4	<.1	55.0	200	6.42	6.0	5.5
MW-92	47.6	<.1	35.0	220	6.58	2.6	4.3

King Salmon
Monitoring Well Water Level

<u>Well</u>	<u>TOC ft.</u>
ESMW-15A	15.00
ESMW-15B	14.90
MW-52	4.32
MW-89	10.58
MW-90	17.33
MW-500	13.30
ESMW-8A	9.92
ESMW-8B	9.80
MW-51	10.38
MW-88	12.95
MW-501	17.72
ESMW-10A	3.94
ESMW-10B	3.63
MW-50	10.54
MW-506	3.30
ESMW-12A	G.L.
ESMW-13A	5.25
ESMW-14	7.71
MW-92C	17.92
EMCON-1	7.98
EMCON-2	11.71
MW-93	12.86
MW-94	13.12
MW-95	13.86
ESMW-13A	15.70
ESMW-2B	17.00
ESMW-2A	17.04
ESMW-4A	16.95
ESMW-4B	16.93
ESMW-5A	8.16
ESMW-5B	8.54
MW-460B	15.72
ESMW-6B	9.14
MW-462C	6.68
MW-435	19.50
MW-653	13.34



Ref: 95-TH61/vg
95-BS2/vg

August 7, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift *SV*

Dear Don:

Attached are the results of 51 field samples for pH, Redox, CO₂, Ferrous Iron, Total Alkalinity, Dissolved Oxygen, Temperature, and Monitoring Well depth from the top of casing as per Service Request #SFTA-1-58. Samples were analyzed July 24, 25, 26, 27, and 28, 1995.

Please note that samples with greater than 5.0 mg/l Ferrous Iron may have interfered with the Hach carbon dioxide color test. If you have any questions concerning these results, please feel free to contact us.

Sincerely,

Tim Hensley
Tim Hensley

Brad Scroggins
Brad Scroggins *TS*

xc: R.L. Cosby
J.L. Seeley *JS*
G.B. Smith

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

King Salmon AFB

Sample	Total Alkalinity mg/L	Ferrous Iron mg/L	CO ₂ mg/L	Redox	pH	D.O. mg/L	Temp °C
KSMW-653	47.6	5.0	55.0	65.0	6.95	2.9	5.4
ESMW-2A	54.4	<.1	35.0	240	6.72	5.1	4.6
ESMW-2B	54.4	<.1	50.0	230	6.50	.4	5.5
ESMW-4A	68.0	<.1	90.0	250	6.52	5.2	4.8
ESMW-1A	81.6	3.0	40.0	35.0	6.81	1.4	4.9
ESMW-1B	68.0	<.1	25.0	150	6.85	2.0	4.6
ESMW-3A	47.6	<.1	30.0	235	6.61	1.4	7.1
ESMW-5A	81.6	<.1	45.0	230	6.73	1.4	8.0
ESMW-5B	74.8	<.1	15.0	200	7.38	0.3	7.0
MW-460B	81.6	<.1	30.0	260	6.62	3.6	5.0
ESMW-6B	54.4	<.1	30.0	250	6.61	0.4	7.6
MW-95	74.8	3.0	35.0	15.0	6.72	0.4	6.1
MW-462-C	40.8	<.1	35.0	145	6.91	1.0	10.0
MW-93	34.0	<.1	30.0	220	6.50	2.5	4.6
MW-435	74.8	<.1	20.0	205	7.19	1.8	5.4
MW-50	40.8	<.1	35.0	245	6.53	11.3	4.3
ESMW-15A	143	25.0	120	-15.0	6.63	0.4	4.8
ESMW-15B	88.4	.25	20.0	5.0	7.01	1.4	5.0
MW-52	95.2	5.0	30.0	-15.0	7.05	2.7	6.5
ESMW-8A	340	40.0	>210	-45.0	6.59	0.1	5.4
ESMW-8B	74.8	.10	10.0	-90.0	7.55	0.2	6.5
MW-501	47.6	<.1	5.0	225	6.49	8.0	4.9
MW-88	54.4	3.0	35.0	85.0	6.73	3.5	4.4
MW-88 Dup	54.4	3.0	35.0	80.0	6.68	---	---
MW-51	116	10.0	90.0	-50.0	6.69	0.5	4.2
MW-500	136	10.0	85.0	-75.0	6.84	0.3	5.1
MW-89	47.6	<.1	25.0	16.5	6.77	0.3	4.9
MW-506	47.6	<.1	5.0	-55.0	7.70	0.3	5.5
MW-90	40.8	<.1	20.0	185	6.86	12.6	4.0
ESMW-10A	109	5.0	55.0	-10.0	6.77	0.6	4.5
ESMW-10B	68.0	<.1	15.0	75.0	7.13	6.9	3.2
ESMW-14	27.2	<.1	55.0	255	6.21	2.4	2.9
ESMW-16	109	25.0	130	-15.0	6.60	0.8	2.1
ESMW-16 Dup	116	25.0	135	-15.0	6.63	---	---

RIC+Mass Chromatogram

Data: 833ESMW8C #1

Scans 1600 to 2200

08/07/95 14:31:00

Cal: 829ESMW8A #3

Sample: 1UL PFB DER(25ML KINGG SALMON ESMW8A) SPLIT 20ML/MIN

Conds.: 50C 1MIN TO 100C 30C/MIN TO 300C 6C/MIN DB5MS60.25.25 SPLITLESS

Range: G 1,4000 Label: N 0, 4.0 Quan: A 0, 1.0 J 0 Base: U 20, 3

100.0 1809

17088.

143

143.043
± 0.500

2085

2011

1927

1852

1809

100.6

17184.

RIC

- M/z 129
- M/z 113
- M/z 141
- M/z 157
- PFB Artifacts

2085

1961

1852

1900

2042

2163

1664 1720

1600

1800

1900

2000

2100

2200

1700

14:10

15:00

15:50

16:40

17:30

18:20

Scan

CHRO:

Figure

RIC
 08/07/95 14:31:00 Data: 833ESMW8C #1 Scans 1000 to 3300
 Sample: 1UL PFB DER(25ML KINGG SALMON ESMW8A) #3 Cali: 829ESMW8A #3
 Conds.: 50C 1MIN TO 100C 30C/MIN TO 300C 6C/MIN DB5MS60.25.25 SPLITLESS
 Range: G 1,4000 Label: N 0, 4.0 Quan: A 0, 1.0 J 0 Base: U 20, 3
 100.0 17184.

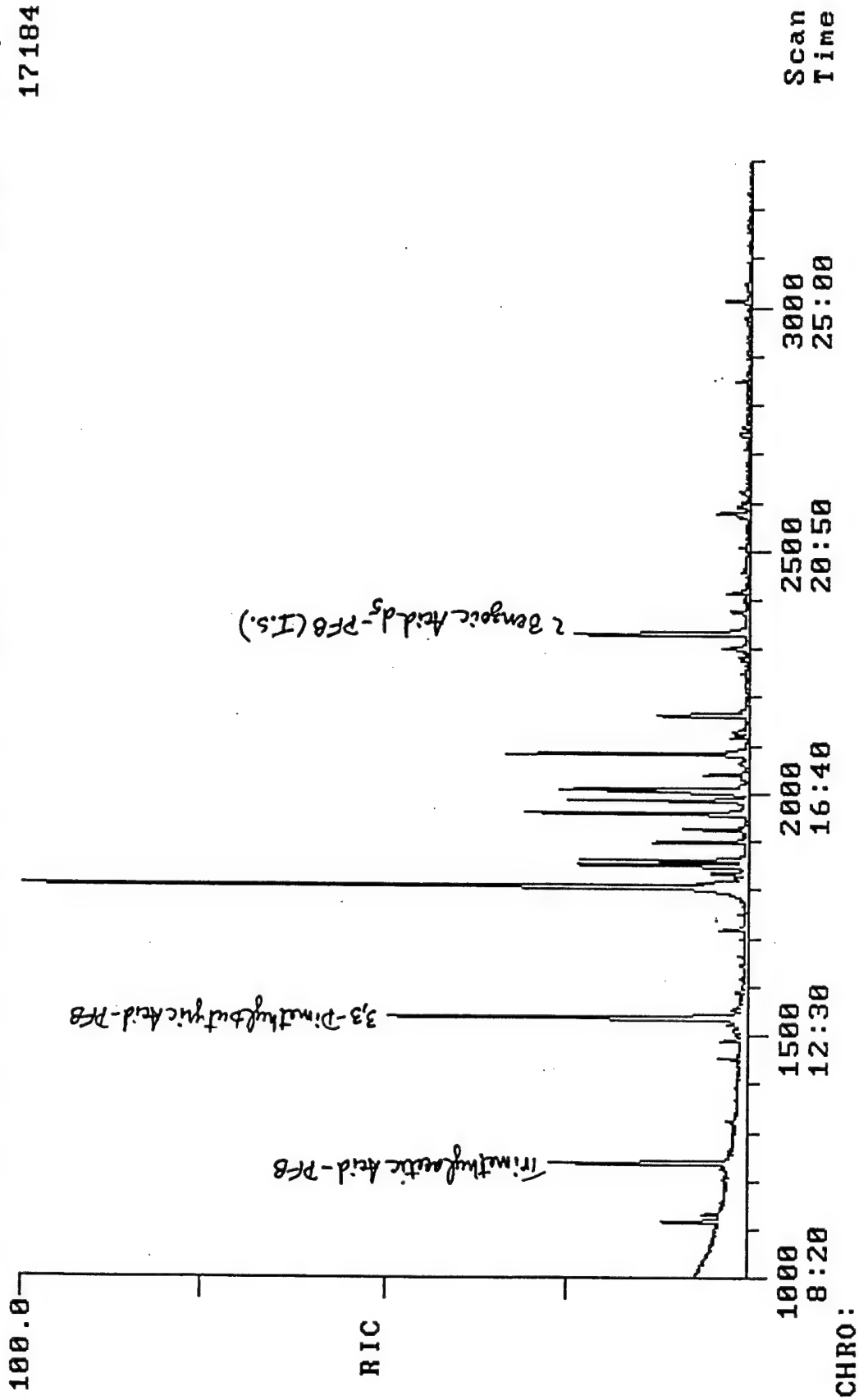


Figure 3

RIC

08/04/95 13:02:00

Data: 833ESMW8A #1
Cali: 833ESMW8A #3

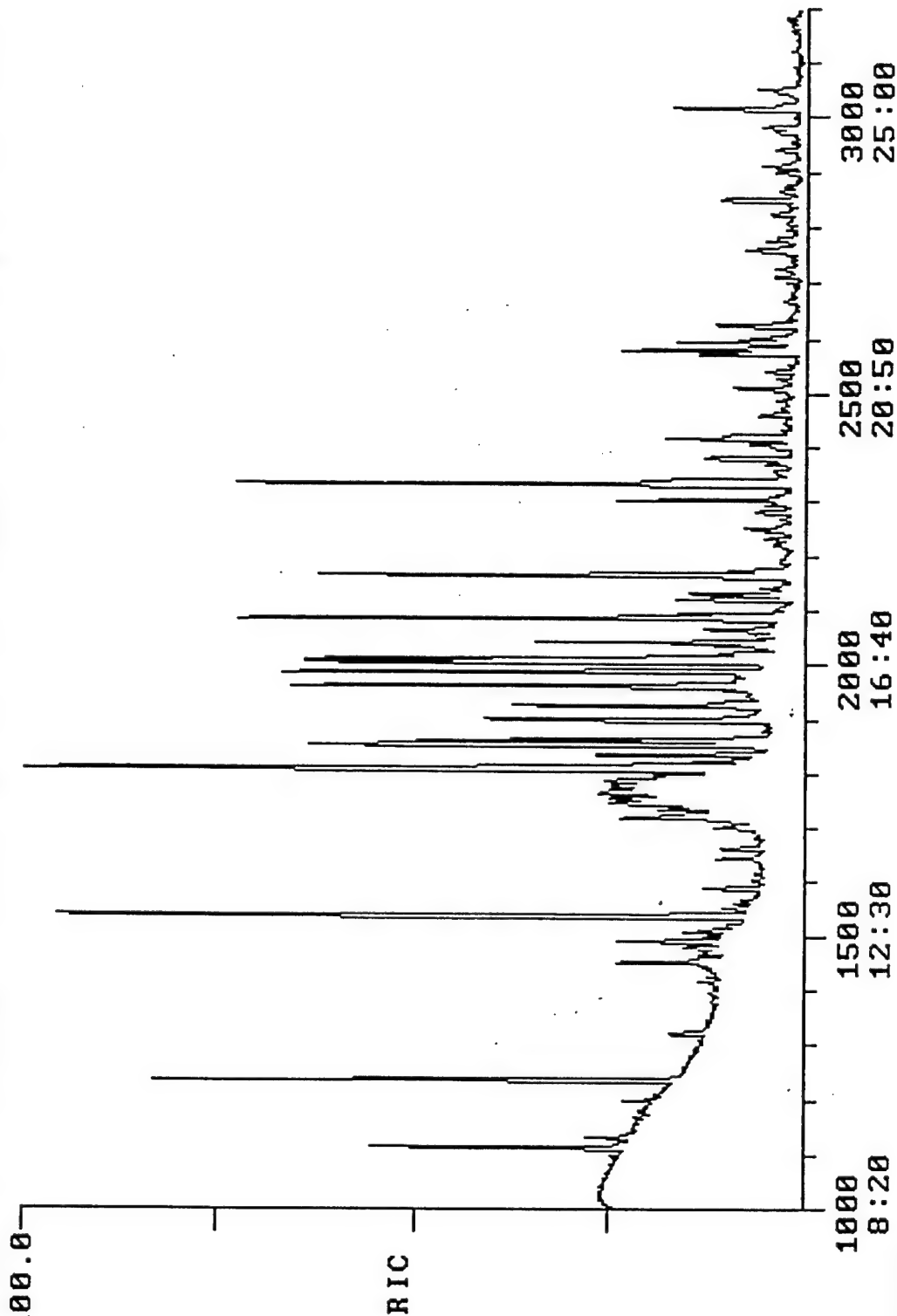
Scans 1000 to 3200

Sample: 1UL PFB DER(25ML KING SALMON ESMW8A + 75ML BLK H2O) + 1PPM BAD5

Conds.: 50C 1MIN TO 100C 30C/MIN TO 300C 6C/MIN DB5MS60.25.25 SPLITLESS

Range: G 1,4000 Label: N 0, 4.0 Quan: A 0, 1.0 J 0 Base: U 20, 3

100.0



CHRO:

1000

8:20

1500

12:30

2000

16:40

2500

20:50

3000

25:00

Scan

Time

22688.

RIC
 08/02/95 22:36:00
 Data: 829ESMW8A #1
 Cali: 829ESMW8A #3
 Sample: 1UL PFB DER 100ML KING SALMON ESMW8A + 1PPM BAD5
 Conds.: 50C TO 100C 30C/MIN TO 300C 6C/MIN DB5MS60.25.25 SPLITLESS
 Range: G 1,4000 Label: N 0, 4.0 Quan: A 0, 1.0 J 0 Base: U 20, 3
 100.0
 23584.

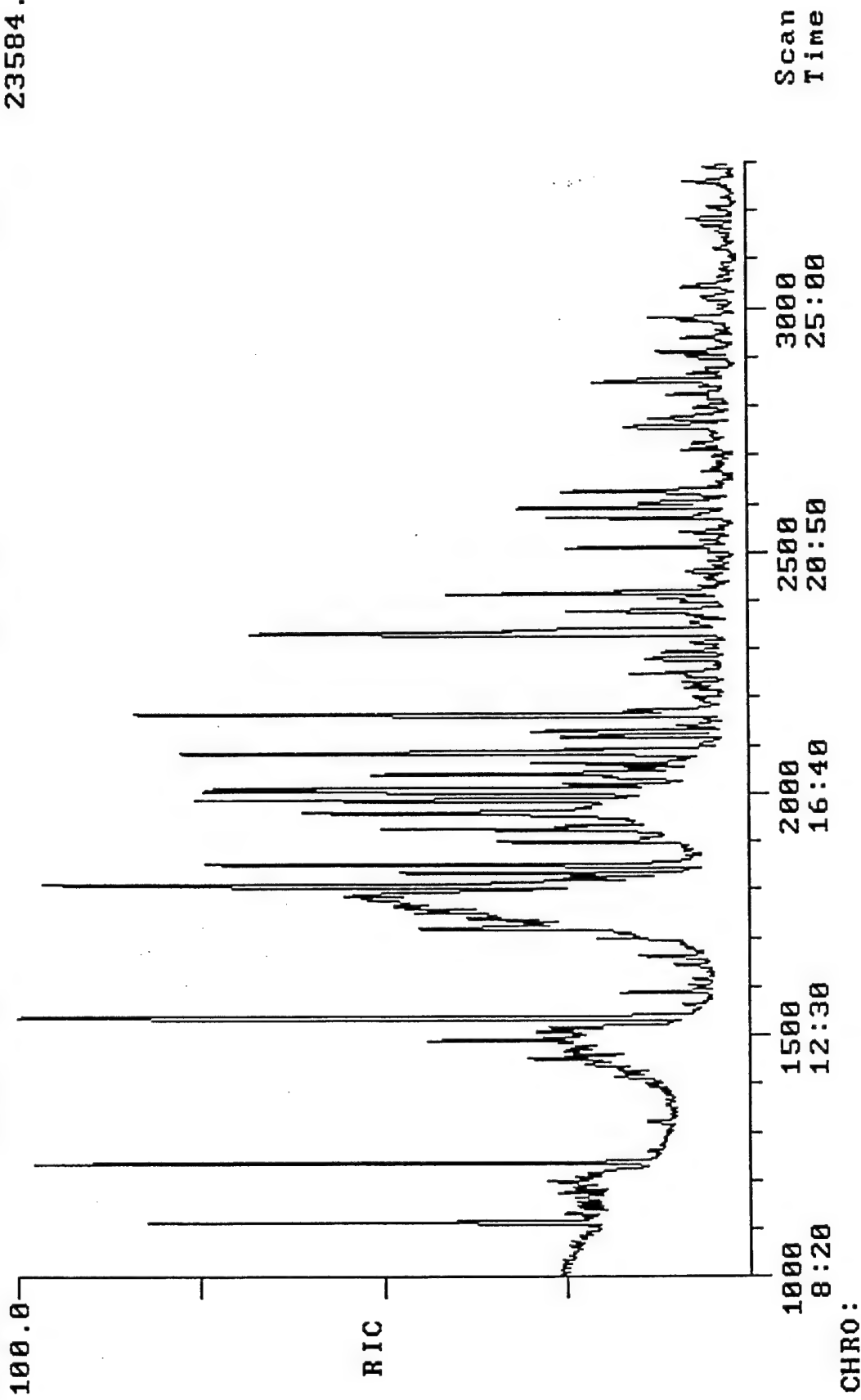


Figure 1

Table 1. Quantitative Report and QC Data for Phenols and Aliphatic and Aromatic Acids
for Sample from MW-3 at KL Avenue Landfill, Kalamazoo, MI (Service Request SF-1-148).

		Concentration ppb			Derivative Standard Blank	Extraction Blank	50 ppb Extraction Recovery	10ppb Check Standard	100ppb Check Standard
		ESMW-158	MW95	ESMW-8A					
1	PROPANOIC ACID - PFB	***	11	389	***	***	8	8	88
2	2-METHYLPROPANOIC ACID - PFB	***	***	30	***	***	18	8	87
3	TRIMETHYL ACETIC ACID - PFB	***	8	720	***	***	47	9	82
4	BUTYRIC ACID - PFB	***	***	47	***	***	15	6	86
5	2-METHYLBUTYRIC ACID - PFB	***	***	24	***	***	42	9	86
6	3-METHYLBUTYRIC ACID - PFB	***	8	19	***	***	40	8	86
7	3,3-DIMETHYLBUTYRIC ACID - PFB	5	15	(1510)*	N.F.	***	55	9	93
8	PENTANOIC ACID - PFB	***	***	25	***	***	44	8	84
9	2,3-DIMETHYLBUTYRIC ACID - PFB	***	***	75	N.F.	N.F.	54	9	90
10	2-ETHYLBUTYRIC ACID - PFB	***	***	18	N.F.	N.F.	55	9	82
11	2-METHYLPENTANOIC ACID - PFB	***	***	19	N.F.	***	56	8	89
12	3-METHYLPENTANOIC ACID - PFB	***	N.F.	54	***	***	55	9	86
13	4-METHYLPENTANOIC ACID - PFB	***	***	29	N.F.	***	55	8	79
14	HEXANOIC ACID - PFB	5	5	10	***	9	61	9	84
15	2-METHYLHEXANOIC ACID - PFB	***	N.F.	N.F.	N.F.	***	59	7	88
16	PHENOL - PFB	***	***	20	***	***	78	6	91
17	CYCLOPENTANECARBOXYLIC ACID - PFB	***	***	50	N.F.	N.F.	46	8	85
18	5-METHYLHEXANOIC ACID - PFB	N.F.	***	44	N.F.	***	56	13	137
19	o-CRESOL - PFB	***	***	9	***	***	57	9	92
20	2-ETHYLHEXANOIC ACID - PFB	***	8	189	***	***	59	7	85
21	HEPTANOIC ACID - PFB	***	***	23	N.F.	8	58	8	85
22	m-CRESOL - PFB	***	***	14	N.F.	***	59	9	94
23	p-CRESOL - PFB	***	***	33	N.F.	***	57	9	96
24	1-CYCLOPENTENE-1-CARBOXYLIC ACID - PFB	***	***	5	N.F.	***	42	8	85
25	o-ETHYLPHENOL - PFB	N.F.	N.F.	N.F.	N.F.	N.F.	58	10	99
26	CYCLOPENTANEACETIC ACID - PFB	N.F.	***	13	N.F.	N.F.	57	11	91
27	2,6-DIMETHYLPHENOL - PFB	N.F.	N.F.	12	N.F.	N.F.	51	10	97
28	2,5-DIMETHYLPHENOL - PFB	N.F.	***	10	N.F.	N.F.	61	9	95
29	CYCLOHEXANECARBOXYLIC ACID - PFB	***	***	34	N.F.	N.F.	58	9	91
30	3-CYCLOHEXENE-1-CARBOXYLIC ACID - PFB	***	***	N.F.	***	***	52	10	90
31	2,4-DIMETHYLPHENOL - PFB	N.F.	***	N.F.	N.F.	N.F.	47	10	98
32	3,5-DIMETHYLPHENOL & m-ETHYLPHENOL - PFB	N.F.	N.F.	7	N.F.	N.F.	59	9	96
33	OCTANOIC ACID - PFB	***	5	30	***	9	64	8	82
34	2,3-DIMETHYLPHENOL - PFB	N.F.	***	N.F.	N.F.	N.F.	57	10	96
35	p-ETHYLPHENOL - PFB	N.F.	N.F.	N.F.	N.F.	N.F.	58	10	99
36	BENZOIC ACID - PFB	***	14	189	***	5	60	8	87
37	3,4-DIMETHYLPHENOL - PFB	N.F.	***	10	N.F.	N.F.	61	9	95
38	m-METHYLBENZOIC ACID - PFB	***	55	528	N.F.	N.F.	50	9	85
39	1-CYCLOHEXENE-1-CARBOXYLIC ACID - PFB	***	N.F.	7	N.F.	N.F.	55	9	86
40	CYCLOHEXANEACETIC ACID - PFB	N.F.	***	18	N.F.	N.F.	60	8	90
41	2-PHENYLPROPANOIC ACID - PFB	N.F.	***	13	N.F.	N.F.	57	9	88
42	o-METHYLBENZOIC ACID - PFB	***	15	203	***	***	62	9	82
43	PHENYLACETIC ACID - PFB	***	11	278	***	***	59	8	88
44	m-TOLYLACETIC ACID - PFB	N.F.	18	572	N.F.	N.F.	51	9	90
45	o-TOLYLACETIC ACID - PFB	N.F.	7	229	N.F.	N.F.	58	9	84
46	2,6-DIMETHYLBENZOIC ACID - PFB	***	***	22	N.F.	N.F.	58	13	103
47	p-TOLYLACETIC ACID - PFB	***	17	329	N.F.	N.F.	61	11	97
48	p-METHYLBENZOIC ACID - PFB	***	7	240	N.F.	***	60	9	89
49	3-PHENYLPROPANOIC ACID - PFB	N.F.	***	18	N.F.	N.F.	62	8	91
50	2,5-DIMETHYLBENZOIC ACID - PFB	N.F.	5	68	N.F.	N.F.	61	9	91
51	DECANOIC ACID - PFB	***	***	17	***	***	62	8	84
52	2,4-DIMETHYLBENZOIC ACID - PFB	***	***	32	N.F.	N.F.	62	9	90
53	3,5-DIMETHYLBENZOIC ACID - PFB	N.F.	N.F.	19	N.F.	N.F.	51	8	85
54	2,3-DIMETHYLBENZOIC ACID - PFB	N.F.	***	25	N.F.	N.F.	64	9	93
55	4-ETHYLBENZOIC ACID - PFB	***	***	298	N.F.	N.F.	59	9	87
56	2,4,6-TRIMETHYLBENZOIC ACID - PFB	***	10	207	N.F.	N.F.	67	10	102
57	3,4-DIMETHYLBENZOIC ACID - PFB	***	***	116	N.F.	N.F.	59	9	84
58	2,4,5-TRIMETHYLBENZOIC ACID - PFB	N.F.	5	29	N.F.	N.F.	62	10	91

* Indicates concentration was above highest calibration standard (1ppm).

*** Indicates concentration of extract was below lowest calibration standard (5 ppb).

N.F. indicates not found.

Ref: 95-DF45

Aug. 10, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift ✓

Dear Don:

As requested in Service Request SF-1-135, GC/MS analysis for phenols and aliphatic/aromatic acids was done on three water samples, ESMW15B, MW95 and ESMW8A from King Salmon Airport. Derivatization of the samples were done by Amy Zhao on August 1, 1995. Twenty-five ml of sample ESMW8A was diluted with 75 ml of acid free water before extraction. This was necessary because the capillary column was overloaded by compounds in the PFB extract. The extracts were analyzed by GC/MS on August 2, 1995. RSKERL SOP 177 was used for the extraction, derivatization and GC/MS analysis of the samples.

Table I provides the concentrations of the phenols and aliphatic/aromatic acids found in the King Salmon Airport samples and quality assurance samples run at the same time as the samples. Spike recoveries for each of the acids and phenols were determined in a 50 ppb spike of 100 ml of water blank. Recovery of the 50 ppb concentration was poor for low molecular weight aliphatic acids due to the poor extraction efficiencies of these acids from water. Higher molecular weight aliphatic and aromatic acids exhibit good recoveries.

Three chromatograms of the PFB extracts of sample ESMW8A are provided to show the column overload. Figure 1 shows the chromatogram of the PFB extract from the undiluted water sample. The column is overloaded by trimethylacetic acid-PFB, 3,3-dimethylbutyric acid-PFB and PFB derivatives which have the 143 m/z ion. Figure 2 shows the chromatogram of the 1/4 dilution of the sample. Here the overloading is less. When this extract is injected under split flow of 20 ml/min (See Figure 3), the overload is diminished considerably.

The familiar pattern of peaks with 143 m/z ions are again present in the chromatogram of ESMW8A and are displayed in Figure 4. This sample contained the highest levels of these compounds found in any sample to date. This sample is presently being

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analyzed by the Tracer GC/FTIR. Preliminary evaluation of the FTIR spectra indicates that the peaks are aliphatic esters. Confirmed identification of the compounds will be attempted as soon as authentic compounds become available. Eight branched chain C₈ aliphatic acids have been located as a result of our literature search.

If you should have any questions, please feel free to contact me.

Sincerely,

Dennis D. Fine

Dennis D. Fine

xc: J.L. Seeley *js*
G.B. Smith
R.L. Cosby

Ref: 95-DF42

Aug 23, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab.
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift *SV**King Salmon*

Dear Don:

This letter reports the first successful analysis of samples on the Bio-Rad Tracer GC/FTIR at RSKERL. Louis Staggs' and my efforts began last July with a trip to Conoco to run samples on their Tracer. Since then we experienced first hand the difficulties of bringing up a system which had been idle for over four years. We returned a MCT detector for re-evacuation of its Dewar, installed a new CO₂ trap system to minimize CO₂ background fluctuations in the purge gas, replaced an cracked ion gauge which was causing poor vacuum, modified an expansion loop in the GC and a connecting spacer between the xyz positioning platform and the transfer line block and installed a new transfer line. We now can align the tip and meet specifications for tip alignment without assistance from a service engineer.

Preliminary GC/MS Analysis

Two water samples, ESMW8A from King Salmon Airport and POMP12S from Pope AFB were recently analyzed for acids and phenols using negative ion chemical ionization (NICI) GC/MS (RSKERL-SOP 177). These samples contained numerous aliphatic carboxylic acids at levels of 1 - 5 ppm and below. The largest peaks among the derivatized acids in both samples have 100% ions at 143 m/z. This ion is expected to be a negative carboxylate ion due to fragmentation of a pentafluorobenzyl ester. These esters could be from branched chain C₈ acids (C₈H₁₅O₂), hydroxy-cyclohexyl carboxylic acids (C₇H₁₁O₃) or C₇ keto-aliphatic acids (C₇H₁₁O₃). Figures 1 and 2 show the total reconstructed NICI chromatogram and extracted ion chromatograms of the 143 m/z ion for these samples. Figure 3 shows the direct comparison of the 143 m/z ions in two samples. Sample POMP12S contains compounds with 143 m/z ions which elute later than compounds in sample ESMW8A. Comparison of the electron impact spectrum of these peaks indicate that the compounds are unique to each sample.

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Of the two profiles shown in Figure 3, the Pope AFB sample is unique in that this distribution has not been seen in any of the hundreds of acid-PFB extracts which I have run. The profile of acid-PFB esters shown in the King Salmon sample has been seen in samples from:

Rickenbacken AFB (MW-5)
Patrick AFB (86 MW9D & 86 MW3M2S)
Eglin AFB (80N2B)
Battle Creek (89ESMP2S, 89ESMP10S & BC-3 MW-2)
Hill AFB (82J)

Tracer GC/FTIR Analysis of Samples POMP12S and ESMW8A.

Extremely dry samples are required for GC/FTIR analysis. The samples were taken to dryness using the Savant concentrator. Methylene chloride which was dried over 5A molecular sieve was added to the dried sample. PFB derivative extracts were concentrated by drying 250 μ l of extract and adding 100 μ l of methylene chloride.

Each PFB extract was injected on the GC/FID side of the Tracer GC before injection into the GC/FTIR side. Identical DB5-MS 30 meter capillary columns with 0.25 mm i.d. and 0.5 μ m film thickness were installed in the GC for GC/FID and GC/FTIR analysis. The helium pressure on the GC/FID side was adjusted so that the retention of acetone injected at 150°C matched the retention of acetone in the GC/FTIR side. The column flow in the GC/FTIR side at 150°C was 0.8 ml/min. GC/FID chromatograms of POMP12S and ESMW8A are shown in Figures 4 and 5.

For the Tracer GC/FTIR analysis, 1 - 2 μ l of sample was injected splitless for 1 minute. Acquisition of the FTIR spectra was not started until after the solvent peak eluted from the transfer tip. The tip was moved to the lowest vertical position of the trough during solvent elution. The transfer line tip was moved to the slide and acquisition was started when compounds were not eluting from the capillary column. This time was determined from the GC/FID chromatogram. The slide speed was set to resolve GC peaks separated by 1 second. This allowed the Tracer profile to match the GC/FID and GC/MS profiles. The deposited trace was scanned by averaging 4 scans every second with a resolution of 8 cm^{-1} . Spectra and both Gram-Schmidt and functional group reconstructed chromatograms were processed using peak edit software supplied by Biorad and then transferred via disk to a PC for additional processing and graphic printing.

Figures 6 and 14 show the Gram-Schmidt chromatograms of PFB derivatives of samples POMP12S and ESMW8A obtained from the Bio-

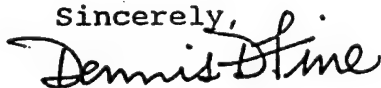
Rad FTS-45 FTIR Spectrometer with GC-Tracer interface. Figures 7-13 and 15-27 are the FTIR spectra of the peaks found in chromatograms of the two samples. Interpretation of these spectra and the electron impact mass spectra gives indications of the character of each compound. While identification cannot be confirmed without analysis of the actual compound, general statements about the nature of the samples can be made.

Peaks which have the 143 m/z ion in the NICI spectra also have absorbances between 3000 and 2800 cm⁻¹. These absorbances correspond to asymmetric and symmetric stretching of CH₃ and CH₂ groups. The relative intensity of absorbances at 2962, 2874 cm⁻¹ (asymmetric and symmetric stretching of CH₃) with respect to 2928, 2860 cm⁻¹ (asymmetric and symmetric stretching of CH₂) indicate that two or more methyl groups are present in the molecule. The presence of only one carbonyl ester absorption at 1734 cm⁻¹ indicates that only one carbonyl is present in the PFB esters. Also the absence of an adsorption near 3300 cm⁻¹ shows that the peaks are not PFB esters of hydroxy-cyclohexyl carboxylic acids. The FTIR spectra indicate that the peaks are branched chain aliphatic carboxylic acids PFB esters. Several of the peaks have absorbances at 1470, 1386 and 1366 cm⁻¹ which indicate that terminal isopropyl groups are present.


Ten of the twenty-two methylheptanoic, dimethylhexanoic and trimethylpentanoic acid isomers have been purchased or obtained as gifts from researchers. Two branched chain acids are soon coming in from England. Literature searches for the other acids have been unsuccessful. Several small organic synthesis companies have prepared some of these acids in the past. The cost for each acid could be about \$500 or more depending on the difficulty in synthesis. If funding is available for commercial synthesis, please let us know. Also, it is possible that simple two step synthetic routes could be done here at RSKERL.

If you should have any questions, please feel free to contact me.

Sincerely,



Dennis D. Fine

xc: J.L. Seeley 
G.B. Smith
R.L. Cosby
J. Wilson
R. L. Staggs(OSU)

Sample	BENZENE	TOLUENE	ETHYLENE	p-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TriMB
QC, OBSERVED, PPB	48.5	50.2	53.0	48.6	47.6	51.2	49.7
QC, TRUE VALUE, PPB	50.0	50.0	50.0	50.0	50.0	50.0	50.0
ESMW-5A	14.3	16.8	7.6	20.4	11.6	14.8	12.2
ESMW-5B	BLQ	ND	0.9	ND	ND	ND	ND
ESMW-6B	ND	ND	ND	ND	ND	ND	ND
ESMW-8A	319	5620	592	368	962	876	161
ESMW-8B	ND	BLQ	BLQ	ND	BLQ	BLQ	ND
ESMW-8B Duplicate	ND	BLQ	BLQ	BLQ	BLQ	BLQ	ND
ESMW-11	ND	1.3	ND	ND	ND	ND	ND
ESMW-12A	3.3	3.8	BLQ	BLQ	ND	ND	ND
ESMW-14	ND	ND	ND	ND	ND	ND	ND
ESMW-15A	BLQ	1.6	27.0	51.4	ND	ND	ND
1 PPB	0.9	0.9	0.9	0.9	0.9	1.1	79.5
ESMW-15B	ND	ND	4.8	11.0	ND	0.9	0.9
ESMW-16	3.7	ND	1.7	1.6	ND	BLQ	6.9
ESMW-16 Duplicate	3.5	ND	1.8	1.6	ND	BLQ	ND
NO LABEL	ND	ND	ND	ND	ND	ND	ND
GP-1	ND	ND	ND	ND	ND	ND	ND
GP-2	ND	BLQ	BLQ	BLQ	BLQ	ND	BLQ
GP-4	BLQ	1.3	0.9	1.0	2.0	1.3	ND
GP-5	2.0	4.7	2.9	3.0	7.1	4.5	1.1
GP-6	2.2	1.6	1.0	1.0	2.3	1.5	BLQ
GP-6 Duplicate	2.1	1.5	1.0	1.1	2.4	1.5	BLQ
10 PPB	9.8	9.8	9.9	10.0	10.0	10.0	9.9
GP-7	ND	ND	ND	ND	ND	ND	ND
GP-8	ND	ND	ND	ND	ND	ND	ND
GP-9	1050	* 4150	706	679	1760	880	245
GP-10	ND	ND	ND	ND	ND	ND	ND
EMCON-1	319	755	456	448	1130	698	187
EMCON-2	BLQ	4.1	BLQ	BLQ	BLQ	BLQ	ND
FT01 SW-1	94.8	52.0	44.3	56.6	64.5	40.0	20.5
FT01 SW-02	4.8	3.5	ND	ND	BLQ	ND	ND
U.N. SITE SW-3	ND	ND	ND	ND	ND	ND	ND
U.N. SITE SW-4	ND	BLQ	ND	ND	ND	ND	ND
U.N. SITE SW-05	ND	ND	ND	ND	ND	ND	ND
U.N. SITE SW-06	ND	ND	ND	ND	ND	ND	ND
QC, OBSERVED, PPB	46.7	50.5	52.0	47.1	47.5	50.0	50.0
QC, TRUE VALUE, PPB	50.0	50.0	50.0	50.0	50.0	50.0	50.0

* = Estimate of the concentration, no field duplicate provided to make dilutions

ND=None Detected; N/A=Not Analyzed; BLQ=Below Limit of Quantitation, 1ppb for all compounds except Naphthalene which = 10 ppb

SampleName	1,2,4-TriMB	1,2,3-TriMB	1,2,4,5-TetraMB	1,2,3,5-TetraMB	1,2,3,4-TetraMB	Naphthalene	Fuel Carbon
100 ppb	109	109	111	109	114	112	N/A
QC, OBSERVED, PPB	56.9	53.8	54.2	57.3	60.1	58.9	N/A
QC, TRUE VALUE, PPB	50.0	50.0	50.0	50.0	50.0	50.0	N/A
MW-10A	29.8	24.9	10.4	13.7	21.7	29.6	518
MW-10B	ND	ND	ND	ND	ND	BLQ	BLQ
MW-50	ND	ND	ND	ND	1.1	BLQ	0.9
MW-51	33.7	27.3	17.0	21.4	33.3	60.5	1060
MW-52	1.6	9.5	6.8	12.2	22.8	BLQ	1050
MW-88	1.5	11.5	5.2	12.4	17.7	BLQ	433
MW-89	12.0	14.6	5.1	9.4	12.0	BLQ	388
MW-90	ND	ND	ND	ND	ND	ND	11.8
MW-92	ND	ND	ND	ND	ND	ND	3.2
MW-93	ND	ND	ND	ND	ND	ND	20.2
10 PPB	10.3	10.3	10.2	10.2	10.3	BLQ	N/A
MW-94	ND	ND	ND	ND	ND	ND	BLQ
MW-95	75.2	43.7	3.6	5.0	6.5	25.4	2240
MW-435	23.2	11.0	1.6	2.1	2.4	13.1	241
MW-460B	ND	ND	ND	ND	ND	ND	8.0
MW-462C	ND	ND	ND	ND	ND	ND	ND
ESMW-500	53.5	66.4	38.8	52.7	65.3	49.8	2420
ESMW-500 Duplicate	52.3	63.6	36.2	49.5	62.9	49.1	2070
MW-501	ND	ND	ND	ND	ND	ND	BLQ
MW-506	ND	ND	ND	ND	ND	ND	5.5
MW-653	272	146	17.7	27.2	41.5	127	* 4480
100 PPB	108	107	110	109	111	107	N/A
WP-1	7.9	6.5	4.1	5.2	9.8	18.8	416
WP-2	ND	ND	ND	ND	ND	ND	273
WP-2 Duplicate	ND	ND	ND	ND	ND	ND	336
WP-3	ND	ND	ND	ND	ND	ND	50.9
ESMW-1A	229	133	10.7	17.0	19.6	69.0	8980
ESMW-1B	ND	ND	ND	ND	ND	BLQ	4.8
ESMW-2A	ND	ND	ND	ND	ND	ND	1.2
ESMW-2B	ND	ND	ND	ND	ND	ND	ND
ESMW-3A	ND	ND	ND	ND	ND	ND	ND
ESMW-4A	ND	ND	ND	ND	ND	ND	ND

* = Estimate of the concentration, no field duplicate provided to make dilutions

Sample	Time	1,2,4-TriMB	1,2,3-TriMB	1,2,4,5-TetraMB	B	1,2,3,5-TetraMB	1,2,3,4-TetraMB	Naphthalene	Carbon
QC, OBSERVED, PPB		50.4	47.3	45.5		48.3	49.2	42.8	N/A
QC, TRUE VALUE, PPB		50.0	50.0	50.0		50.0	50.0	50.0	N/A
ESMW-5A		22.1	11.4	2.7		3.3	4.4	21.3	275
ESMW-5B		ND	ND	ND		ND	ND	ND	1.3
ESMW-6B		ND	ND	ND		ND	ND	ND	N/A
ESMW-8A		470	398	25.6		65.6	129	225	13330
ESMW-8B		ND	BLQ	2.1		1.6	24.6	ND	94.7
ESMW-8B Duplicate		ND	BLQ	2.1		1.6	24.2	ND	99.7
ESMW-11		ND	ND	ND		ND	ND	ND	1.1
ESMW-12A		ND	ND	ND		ND	ND	BLQ	63.2
ESMW-14		ND	ND	ND		ND	ND	ND	ND
ESMW-15A		ND	27.9	27.1		39.2	52.0	73.8	1670
1 PPB		1.2	1.0	1.0		0.9	1.0	N/A	N/A
ESMW-15B		ND	12.9	15.7		17.9	37.8	30.6	552
ESMW-16		BLQ	ND	ND		ND	ND	ND	21.0
ESMW-16 Duplicate		1.3	1.1	1.8		1.9	3.1	BLQ	37.4
NO LABEL		ND	ND	ND		BLQ	1.6	BLQ	6.9
GP-1		ND	ND	ND		ND	ND	ND	ND
GP-2		ND	ND	ND		ND	ND	ND	BLQ
GP-4		1.0	ND	ND		ND	ND	ND	8.5
GP-5		3.4	1.2	ND		ND	ND	ND	37.3
GP-6		1.1	ND	ND		ND	ND	ND	24.7
GP-6 Duplicate		1.3	BLQ	ND		1.2	1.8	BLQ	34.0
10 PPB		10.1	10.1	10.3		10.3	11.2	12.8	N/A
GP-7		ND	ND	ND		ND	ND	ND	ND
GP-8		ND	ND	ND		ND	ND	ND	ND
GP-9		795	263	35.0		55.9	78.5	366	* 12800
GP-10		ND	ND	ND		ND	ND	ND	ND
EMCON-1 - FT01-F09		556	209	26.8		42.7	60.2	230	6680
EMCON-2 FT01-F08		ND	ND	ND		ND	ND	ND	5.8
FT01 SW-1		24.7	16.3	8.0		10.7	15.6	21.6	772
FT01 SW-02		ND	ND	ND		ND	ND	BLQ	7.6
U.N. SITE SW-3		ND	ND	ND		ND	ND	ND	ND
U.N. SITE SW-4		ND	ND	ND		ND	ND	ND	BLQ
U.N. SITE SW-05		ND	ND	ND		ND	ND	ND	ND
U.N. SITE SW-06		ND	ND	ND		ND	ND	ND	ND
QC, OBSERVED, PPB		49.5	45.9	44.2		47.1	47.2	41.9	N/A
QC, TRUE VALUE, PPB		50.0	50.0	50.0		50.0	50.0	50.0	N/A

* = Estimate of the concentration, no field duplicate provided to make dilutions

Ref: 95-LB57
August 9, 1995

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Ada, OK 74820

THRU: Steve Vandegrift SV

Dear Don:

Please find attached the analytical results for Service Request SF-1-135, King Salmon Airport, requesting the analysis of up to 48 groundwater samples to be analyzed for BTEXXX, TriMBs, TetraMBs, Naphthalene and Total Fuel Carbon. A total of 57 samples were received, most in duplicate, in capped, 40 mL VOA vials on July 31-August 2, 1995. The samples were analyzed on August 2-7, 1995. The samples were stored at 4°C until analyzed. All samples were acquired and processed using the Millennium data system. A 1-500 ppb external calibration curve was used to determine the concentration of the TetraMBs, a 10-500 ppb external calibration curve was used to determine the concentration of Naphthalene, and a 1-1000 ppb external calibration curve was used to determine the concentration of the remaining compounds.

Please note: No duplicates were provided for the following samples "MW-653" and "GP-9". Both samples exceeded the calibration limit for Toluene therefore, a concentration estimate is provided for this compound and Total Fuel Carbon. Also, it was determined during analysis that Naphthalene has a 5% carry over rate.

RSKSOP-133 "Simultaneous Analysis of Aromatics and Total Fuel Carbon by Dual Column-Dual Detector for Ground Water Samples" was used for these analyses. Auto-sampling was performed using a Dynatech autosampler in-line with a Tekmar LSC 2000 sample concentrator.

Sincerely,



Lisa R. Black

xc: R.L. Cosby
G.B. Smith
J.T. Wilson
J.L. Seeley JS

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

SampleName	BENZENE	TOLUENE	ETHYLBENZENE	p-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TriMB
100 ppb	107	106	106	109	106	108	108
QC, OBSERVED, PPB	56.8	55.8	46.3	53.2	52.7	56.5	55.6
QC, TRUE VALUE, PPB	50.0	50.0	50.0	50.0	50.0	50.0	50.0
MW-10A	6.6	1.2	16.1	30.7	ND	24.3	11.6
MW-10B	ND	ND	ND	ND	ND	ND	ND
MW-50	ND	ND	ND	ND	ND	ND	ND
MW-51	4.7	88.6	49.6	54.7	61.1	40.0	36.5
MW-52	62.6	116	58.8	32.8	38.3	24.4	7.5
MW-88	ND	ND	BLQ	1.5	ND	ND	4.7
MW-89	BLQ	ND	1.8	2.5	2.9	2.4	8.2
MW-90	ND	1.4	BLQ	ND	BLQ	BLQ	ND
MW-92	ND	2.5	ND	ND	BLQ	ND	ND
MW-93	BLQ	5.6	BLQ	0.9	2.2	1.4	ND
10 PPB	10.2	9.9	10.0	10.2	9.9	10.1	10.2
MW-94	ND	BLQ	ND	ND	ND	ND	ND
MW-95	349	1010	90.3	99.0	290	180	33.2
MW-435	28.2	1.4	17.7	31.7	ND	2.2	10.6
MW-460B	BLQ	4.1	BLQ	BLQ	BLQ	BLQ	ND
MW-462C	ND	ND	ND	ND	ND	ND	ND
ESMW-500	BLQ	3.7	47.5	77.8	22.8	20.3	77.6
ESMW-500 Duplicate	BLQ	2.7	45.3	74.7	22.0	19.7	76.5
‡ MW-501	ND	BLQ	BLQ	ND	ND	ND	ND
MW-506	ND	3.1	ND	ND	ND	ND	ND
MW-653	357	* 1420	200	210	559	385	95.7
100 PPB	113	108	107	105	109	106	108
WP-1	12.8	1.2	17.4	21.9	6.4	7.4	4.2
WP-2	3.2	BLQ	ND	BLQ	ND	BLQ	ND
WP-2 Duplicate	3.1	BLQ	ND	BLQ	ND	BLQ	ND
WP-3	1.6	21.3	ND	ND	ND	ND	ND
ESMW-1A	796	5400	399	371	1030	619	86.1
ESMW-1B	BLQ	1.2	ND	ND	BLQ	BLQ	ND
ESMW-2A	ND	0.9	ND	ND	ND	ND	ND
ESMW-2B	ND	ND	ND	ND	ND	ND	ND
ESMW-3A	ND	ND	ND	ND	ND	ND	ND
ESMW-4A	ND	ND	ND	ND	ND	ND	ND

* = Estimate of the concentration, no field duplicate provided to make dilutions

ND=None Detected; N/A=Not Analyzed; BLQ=Below Limit of Quantitation, 1ppb for all compounds except Naphthalene which = 10 ppb

MANTECH TECH

Ref: 95-DK28/vg

September 6, 1995

Dr. Don Kampbell
R.S. Kerr Environmental Research Lab
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift *SV*

King Salmon

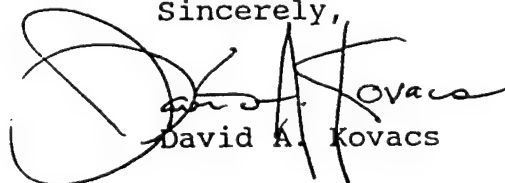
Dear Dr. Kampbell:

This report contains the results of my GC/MSD analysis of King Salmon AFB core extracts for quantitation of benzene, toluene, ethylbenzene (EB), p-Xylene, m-Xylene, o-Xylene, 1,3,5-trimethylbenzene (1,3,5-TMB), 1,2,4-trimethylbenzene (1,2,4-TMB) and 1,2,3-trimethylbenzene (1,2,3-TMB) trichloroethene (TCE) and tetrachloroethene (PCE) as per Service Request #SF-1-135.

The analytical method was a modification of RSKSOP-124. Cool on-column injection (0.5 μ l) was used with electronic pressure control set for a constant flow of 0.9 ml/min. A 30 m X 0.25 mm Restek Stabilwax (Crossbonded Carbowax-PEG, 0.5 μ m film) capillary GC column with 9" X 0.53 mm ID uncoated capillary precolumn was used. The ions chosen were those listed in EPA method 524.2 Revision 3.0. Standards calibration ranged from 0.05 to 250 μ g/ml. A complete report detailing the acquisition method and calibration curve have been recorded. The samples were extracted by Mark Blankenship August 2, 1995 and GC/MSD data acquisition was August 31, 1995.

If I can be of further assistance, please feel free to contact me.

Sincerely,


David A. Kovacs

xc: R.L. Cosby
J.L. Seeley *JS*
G.B. Smith

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 405-436-8660 FAX 405-436-8501

FTOI

[illegible]

Check Standards

(ug/ml)		ND		BLQ		ND		BLQ		ND		BLQ		ND		BLQ		ND	
Method Blank		ND		BLQ		ND		BLQ		ND		BLQ		ND		BLQ		ND	
250	250	2.61E+02	2.61E+02	2.65E+02	2.55E+02	2.37E+02	2.70E+02	2.39E+02	2.52E+02	2.68E+02	2.50E+02	2.58E+02	2.63E+02	2.55E+02	2.42E+02	2.56E+02	2.63E+02	2.55E+02	2.42E+02
250	250	2.39E+02	2.39E+02	2.35E+02	2.46E+02	2.27E+02	2.31E+02	2.61E+02	2.48E+02	2.63E+02	2.55E+02	2.42E+02	2.56E+02	2.63E+02	2.55E+02	2.42E+02	2.56E+02	2.63E+02	2.55E+02
5	5	4.54E+00	4.92E+00	4.83E+00	4.88E+00	4.64E+00	4.46E+00	4.83E+00	4.87E+00	5.32E+00	5.67E+00	4.72E+00	5.32E+00	5.67E+00	4.72E+00	5.22E+00	5.32E+00	5.67E+00	4.72E+00
5	5	4.88E+00	4.85E+00	4.27E+00	4.60E+00	5.29E+00	5.40E+00	5.38E+00	5.39E+00	5.32E+00	5.26E+00	5.22E+00	5.32E+00	5.26E+00	5.22E+00	5.22E+00	5.32E+00	5.26E+00	5.22E+00

7/95

King Salmon
Monitoring Well Water Level

<u>Well</u>	<u>TOC ft.</u>
✓ ESMW-15A	15.00
✓ ESMW-15B	14.90
✓ MW-52	4.32
✓ MW-89	10.58
✓ MW-90	17.33
✓ MW-500	13.30
✓ ESMW-8A	9.92
✓ ESMW-8B	9.80
✓ MW-51	10.38
✓ MW-88	12.95
✓ MW-501	17.72
✓ ESMW-10A	3.94
✓ ESMW-10B	3.63
✓ MW-50	10.54
✓ MW-506	3.30
✓ ESMW-12A	G.L.
✓ ESMW-13A	5.25
✓ ESMW-14	7.71
MW-92C	17.92
EMCON-1	7.98
EMCON-2	11.71
MW-93	12.86
MW-94	13.12
MW-95	13.86
✓ ESMW-13A	15.70
ESMW-2B	17.00
ESMW-2A	17.04
ESMW-4A	16.95
ESMW-4B	16.93
ESMW-5A	8.16
ESMW-5B	8.54
MW-460B	15.72
ESMW-6B	9.14
MW-462C	6.68
MW-435	19.50
MW-653	13.34

SAME?

ATTACHMENT B
ANALYTICAL RESULTS
SEPTEMBER 1998

MANTECH TECHNOLOGY

Ref: 98-MB12
Contract# 68-C-98-138
September 18, 1998

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: Dr. D. Fine *fine*

Dear Don:

Please find attached the analytical results for King Salmon AFB, AK, Service Request SF-0-13 requesting the analysis of monitoring well samples to be analyzed for MTBE, benzene, toluene, ethylbenzene, p-, m-, and o-xylene, 1,3,5-, 1,2,4-, and 1,2,3-trimethylbenzene, naphthalene and total fuel carbon. We received your 16 samples September 10, 1998 in capped, lead lined 40 mL VOA vials. The samples were analyzed on September 15 and 16, 1998. Samples were stored at 4°C until analyzed. Please note: sample ESMW-8A was diluted 1:10 with boiled milli-Q water. All samples were acquired and processed using the Millennium data system. A 5 point (1-1000 ppb) external calibration curve was used to determine the concentration for all compounds.

RSKSOP-133 "Simultaneous Analysis of Aromatics and Total Fuel Carbon by Dual Column/Dual Detector Gas Chromatography in Ground Water Samples" was used for these analyses. Autosampling was performed using a Dynatech-Precision autosampler in-line with a Tekmar LSC 2000 sample concentrator.

Sincerely,

Mark Blankenship
Mark Blankenship

xc: R.L. Cosby
G.B. Smith
J.L. Seeley *JS*

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

SAMPLE NAME	MTBE	BENZENE	TOLUENE	ETHYL BENZENE	P-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB	NAPHTHALENE	FUEL CARBON
GC LAB BLANK	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QC, OBSERVED, 20PPB	18.3	18.4	18.1	18.3	19.3	19.0	19.1	19.2	19.5	18.1	N/A	N/A
QC, TRUE VALUE, 20PPB	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	N/A	N/A
ESMW-1A	13.7	75.2	ND	275.8	308.0	961.4	470.0	83.6	212.8	102.9	59.7	2624
ESMW-1A LAB DUPLICATE	11.4	71.9	ND	251.7	284.2	888.2	441.2	79.0	201.0	97.4	56.7	2426
ESMW-1B	ND	ND	1.8	ND	ND	1.1	ND	ND	ND	ND	ND	3.0
ESMW-2A	ND	ND	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND
100 PPB STD	91.2	92.0	84.0	97.9	97.5	97.1	95.2	98.6	96.5	94.6	90.1	N/A
ESMW-3A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ESMW-4A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ESMW-5A	13.9	418.8	3.4	99.8	147.7	271.2	180.6	46.7	109.7	52.4	30.5	1574
ESMW-6A	11.0	169.4	4900	405.0	280.2	753.9	6,11.39	112.9	331.9	250.7	184.1	9383
ESMW-6B	ND	ND	3.1	BLQ	BLQ	1.2	1.2	1.1	1.2	1.4	BLQ	31.0
ESMW-15A	3.8	BLQ	1.5	44.4	57.6	ND	1.5	13.5	ND	13.9	82.2	606.0
ESMW-15B	ND	BLQ	BLQ	8.5	9.4	BLQ	2.1	1.9	ND	13.4	17.1	263.0
MW-51	154.1	2.5	72.1	112.2	139.0	115.6	18.2	90.8	76.7	29.5	134.9	1609
MW-88	1.6	ND	BLQ	1.9	4.1	2.1	3.3	6.0	6.6	11.0	BLQ	221.0
10 PPB STD	ND	68.3	611.2	63.6	84.2	221.1	121.8	26.6	58.0	30.2	20.8	1336.0
MW-503	8.9	8.8	9.0	8.8	8.8	8.7	8.9	8.7	8.6	8.8	9.0	N/A
WP-1A	2.4	1.3	4.3	44.7	76.7	62.8	54.2	100.6	156.4	124.2	63.5	1806
WP-1B	2.4	23.1	1.6	50.5	69.1	76.7	37.7	34.3	106.9	77.9	56.8	1032
WP-1B LAB DUPLICATE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND = None Detected; BLQ = Below Limit of Quantitation, 1ppb; N/A = Not Analyzed

MANTECH TECHNOLOGY

September 23, 1998
Ref: 98-LP27/lp
Contract # 68-C-98-138

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection & Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74821-1198

THRU: D.D. Fine *fine*

Dear Don:

Attached are inorganic results for a set of 16 samples from King Salmon AFB, Alaska, submitted to MERSC under Service Request # SF-0-13. The samples were received September 10 and were analyzed September 11, 1998. The methods used for these samples were Lachat FIA methods 10-107-06-1-A for ammonia and 10-107-04-2-A for nitrate + nitrite and Waters capillary electrophoresis method N-601 for chloride and sulfate.

Quality assurance measures performed on this set of samples included spikes, duplicates, known AQC samples and blanks.

If you have any questions concerning this data, please feel free to contact me.

Sincerely,

Lynda Pennington
Lynda Pennington

xc: R.L. Cosby
J.L. Seeley *JS*
G.B. Smith

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Center, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 580-436-8660 FAX 580-436-8501

SAMPLE	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	Chloride (mg/L)	Sulfate (mg/L)
ESMW-1A*	<.1	<.1	2.82	2.17
ESMW-1B*	0.50	<.1	3.25	2.52
ESMW-2A*	0.58	<.1	1.96	5.10
ESMW-3A*	0.27	<.1	2.44	4.06
ESMW-4A*	0.61	<.1	2.31	3.22
ESMW-5A*	<.1	<.1	2.73	1.40
ESMW-5A dup	---	<.1	2.69	1.39
ESMW-8A*	<.1	0.11	2.68	0.20
ESMW-8B*	<.1	0.62	2.79	1.46
ESMW-15A*	<.1	0.25	4.45	0.35
ESMW-15B*	<.1	<.1	5.08	0.33
ESMW-15B	<.1	<.1	---	---
MW-51*	0.46	<.1	2.71	1.95
MW-88*	<.1	<.1	3.76	6.23
MW-95	<.1	0.20	3.68	1.62
MW-500	<.1	0.26	3.33	1.70
WP-1A	<.1	<.1	4.75	0.97
WP-1A dup	<.1	<.1	4.73	0.95
WP-1B	0.35	0.31	3.56	2.46
Blank	<.1	<.1	<.5	<.5
WPO39	1.04	0.79	11.0	57.0
WPO39 T.V.	1.10	0.84	10.8	58.0
Spike Recovery	99%	100%	100%	99%



Ref: 98JAD18

Contract # 68-C-98-138

September 22, 1998

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: Dr. Dennis Fine *DFine*

Dear Don:

As requested in Service Request # SF-0-13, headspace GC/MS analysis of 15 King Salmon water samples for chlorinated volatile organics was completed. The samples were received of September 10, 1998 and analyzed on September 16, 1998. (RSKSOP-148 (Determination of Volatile Organic Compounds in Water by Automated Headspace Gas Chromatography/Mass Spectrometry (Saturn II Ion Trap Detector) was used for this analysis.

An internal standard calibration method was established for the 15 compounds. The standard curves were prepared from 1.0 to 5000 ppb. The lower calibration limits were 1.0 ppb.

If you should have any questions, please feel free to contact me.

Sincerely,

John Allen Daniel
John Allen Daniel

xc: R.L. Cosby
G.B. Smith
J.L. Seeley *JL*

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Center, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 580-436-8660 FAX 580-436-8501

Table 1. Quantitation Report for S.R. # SF-0-13 from King Salmon.

Concentration = ppb

Compound	ESMW1A	ESMW1B	ESMW2A	ESMW3A	ESMW4A	ESMW5A	ESMW5A Field Dup	WP1A	WP1B	ESMW8B	ESMW15A
VINYL CHLORIDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
T-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-DICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	1.2	ND	ND	ND
C-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHLOROFORM	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-TRICHLOROETHANE	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CARBON TETRACHLORIDE	ND	ND	ND	ND	ND	ND	ND	ND	2.0	ND	ND
1,2-DICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TETRACHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,3-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
VINYL CHLORIDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
T-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-DICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHLOROFORM	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-TRICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CARBON TETRACHLORIDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-DICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TETRACHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,3-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Compound	ESMW15B	MW51	MW88	MW95	MW95 Lab Dup	MW8A	QC0916A 20 ppb	QC0916B 200 ppb	QC0916C 20 ppb	QC0916F 200 ppb	BL0916A
VINYL CHLORIDE	ND	ND	ND	ND	ND	ND	18.2	178	19.8	185	ND
1,1-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	22.9	220	23.0	230	ND
T-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	20.1	197	19.7	205	ND
1,1-DICHLOROETHANE	ND	ND	ND	ND	ND	ND	21.6	220	23.3	220	ND
C-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	21.1	218	22.0	214	ND
CHLOROFORM	ND	ND	ND	ND	ND	ND	21.4	209	22.0	203	ND
1,1,1-TRICHLOROETHANE	ND	ND	ND	ND	ND	ND	20.6	200	21.3	211	ND
CARBON TETRACHLORIDE	ND	ND	ND	ND	ND	ND	20.5	202	21.7	209	ND
1,2-DICHLOROETHANE	ND	ND	ND	ND	ND	ND	21.8	231	21.9	215	ND
TRICHLOROETHENE	ND	ND	ND	ND	ND	ND	18.7	185	19.4	186	ND
TETRACHLOROETHENE	ND	ND	ND	ND	ND	ND	20.8	203	20.5	201	ND
CHLOROBENZENE	ND	ND	ND	ND	ND	ND	21.8	215	21.9	214	ND
1,3-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	21.8	206	21.7	212	ND
1,4-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	22.1	217	22.2	212	ND
1,2-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	22.6	218	22.6	219	ND

ND = None Detected --- = Below Calibration Limit(1.0 ppb) QC = Quality Control Std BL = Blank Dup = Duplicate

MANTECH TECHNOLOGY

Ref: 98-AZ16
68-C-98-138

September 14, 1998

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: D. Fine *DFine*

Dear Don:

As requested in Service Request #SF-0-13, gas analysis was performed for methane, ethylene, and ethane on samples from King Salmon Airport. The samples were received on September 10, 1998. The analyses were performed on September 11, 1998. These analyses were performed as per RSKSOP-194, and the calculations were done as per RSKSOP-175.

If you should have any questions, please feel free to contact me.

Sincerely,

Amy Q. Zhao
Amy Zhao

xc: R.L. Cosby
G.B. Smith
J.L. Seeley *JLS*

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Center, P.O. Box 1198, 919 Kerr Research Drive
Ada, Oklahoma 74821-1198 580-436-8660 FAX 580-436-8501

Sample	Methane	Ethylene	Ethane
100 ppm CH4	97.3	**	**
100 ppm C2H4	**	101.2	**
100 ppm C2H6	**	**	103.1
HP. Helium Blank	**	**	**
Lab Blank	**	**	**
ESMW-1A	**	**	**
ESMW-1B	**	**	**
ESMW-2A	**	**	**
ESMW-3A	**	**	**
ESMW-4A	**	**	**
ESMW-4A Lab DuP	**	**	**
ESMW-5A	0.07	**	**
ESMW-8A	0.64	*	0.004
ESMW-8B	0.13	**	**
ESMW-15A	3.35	**	**
ESMW-15B	0.01	**	**
ESMW-15B Field Dup	0.01	**	**
10,000 PPM CH4	1.05E+04	**	**
MW-51	0.02	**	**
MW-88	**	**	**
MW-95	0.06	**	**
MW-500	0.34	**	**
MW-1A	5.86	**	**
MW-1B	**	**	**
MW-1B Field Dup	**	**	**
10 PPM CH4	10.0	**	**
10 PPM C2H4	**	10.1	**
10 PPM C2H6	**	**	10.0
1000 PPM CH4	1.06E+03	**	**
Lower Limit of Quantitation	0.001	0.003	0.002

Units for the standards are parts per million.

** denotes None Detected.

MANTECH TECHNOLOGY

Ref: 98-SH16
Contract # 68-C-98-138

September 16, 1998

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection & Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: D.D. Fine *fine*

Dear Don:

Attached are TOC results for a set of 16 King Salmon liquids submitted September 11, 1998 under Service Request #SF-0-13. Sample analysis was begun September 16, 1998 and completed September 16, 1998 using RSKSOP-102.

Blanks, duplicates, AQC samples were analyzed along with your samples, as appropriate, for quality control. If you have any questions concerning this data, please feel free to ask me.

Sincerely,

Sharon Hightower
Sharon Hightower

xc: R.L. Cosby
G.B. Smith
J.L. Seeley *JS*

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

KAMPBELL KING SALMON LIQUIDS SF-0-13

SAMPLE	MG/L TOC
ESMW-1A	11.9
ESMW-1B	1.28
ESMW-2A	5.64
ESMW-3A	4.29
ESMW-4A	4.85
ESMW-5A	8.92
ESMW-8A	56.0
ESMW-8B	2.89
ESMW-15B	8.24
WP-1A	17.6
DUP	17.8
WP39	77.0

WP39 std. t.v.=76.0+/-7.60

*** = couldn't determine an endpoint for CO₂ due to high concentration of ferrous iron.

ATTACHMENT C
RESPONSES TO COMMENTS

PARSONS

Parsons Engineering Science, Inc. • A Unit of Parsons Infrastructure & Technology Group Inc.

1700 Broadway, Suite 900 • Denver, Colorado 80290 • (303) 831-8100 • Fax: (303) 831-8208 • www.parsons.com

11 October 1999

Mr. Jerry Hansen
Technical Program Manager
AFCEE/ERT
3207 North Road, Bldg. 532
Brooks AFB, TX 78235-5363

Subject: Responses to AFCEE Comments on the Draft Intrinsic Remediation
Treatability Study Addendum for the Upper Naknek Site (SS-12), King
Salmon Airport, Alaska

Dear Mr. Hansen:

This letter provides responses to comments received on the Draft Intrinsic Remediation Treatability Study (TS) Addendum for the Upper Naknek Site (SS-12), King Salmon Airport, Alaska. This draft addendum was prepared by Parsons Engineering Science, Inc. (Parsons ES) for the Air Force Center for Environmental Excellence Technology Transfer Division (AFCEE/ERT) and Elmendorf Air Force Base (AFB).

The intent of the addendum was to evaluate natural attenuation over time for the remediation of groundwater contaminated with fuel hydrocarbons at the Upper Naknek site. The draft addendum was submitted to AFCEE in September 1999. Comments on the draft addendum were received from AFCEE as reviewed by Mr. Jon Atkinson of AFCEE/ERT, dated 8 October 1999. Responses to these comments were prepared by Parsons ES and are presented herein.

Comment 1) Page 4, Sec 1.2, Para 1, Line 9: To correct subject-verb agreement, recommend changing "was constructed" to "were constructed."

Parsons ES Response: The editorial correction will be made.

Comment 1) Page 4, Sec 1.2, Para 1, Line 9: To correct subject-verb agreement, recommend changing "was constructed" to "were constructed."

Parsons ES Response: The editorial correction will be made.

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Comment 2) Page 15, Sec 2.1, Para 1: Recommend rounding calculated groundwater velocities to two significant figures, to better reflect accuracy/certainty of these calculated values.

Parsons ES Response: *Groundwater velocities will be reported to two significant figures as suggested.*

Comment 3) Page 16, Sec 2.2, Para 3, Sent 1: "has expanding" should be "has expanded."

Parsons ES Response: *The editorial correction will be made.*

1. Comment 4) Page 24, Sec 2.6:

- a. Recommend adding a concise rationale for not evaluating manganese as an electron acceptor at SS-12.
- b. Suggest adding a brief discussion (including interpretation) of the ammonia analyses.

Parsons ES Response:

- a. *Manganese was not analyzed for at the discretion of the US Environmental Protection Agency (USEPA) National Risk Management Research Laboratory (NRMRL) scientists.*
- b. *Ammonia was only detected at low concentrations in three wells in September 1998. No conclusions can be made from these limited data. Ammonia was not previously measured at the site, therefore, there is no basis for comparison.*

Comment 5) Pages 24 and 25, Sec 2.6, Para 2, Sents 1 and 4: Recommend adding manganese to the list of inorganic electron acceptors.

Parsons ES Response: *Manganese will be added to the list of electron acceptors as recommended.*

Mr. Jerry Hansen
11 October 1999
Page 3

If you have any questions, have additional comments, or require additional information, please call me at (303) 831-8100.

Sincerely,

PARSONS ENGINEERING SCIENCE, INC.

Bruce M. Henry
Bruce M. Henry, P.G.
Project Manager

cc: File 722450.11000